THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 12 APRIL, 1948 NUMBER 2

RELEASERS OF ATTACK BEHAVIOR PATTERN IN SHARK AND BARRACUDA

Bruce S. Wright

Director, Northeastern Wildlife Station, Wildlife Management Institute, Fredericton, N. B.

INTRODUCTION

The last two and a half years of the author's war service were spent in commanding and training the British Sea Reconnaissance Unit. In the course of this training underwater work was carried on by a unit of forty men on the coasts of California, the Bahamas, Ceylon and Burma. Careful field notes were made of the behavior of the dangerous marine fauna encountered during these operations and these notes form the basis of this paper. All the encounters quoted here took place at the Bahamas Station which was on Salt Key, three miles northeast of New Providence Island, between January and May 1944.

The dangerous sharks tentatively identified at this station were the Brown or Ground Shark, *Carcharinus galeolamna;* Hammerhead Shark, *Sphyrna* sp.; Tiger Shark, *Galeocerdo arcticus;* and the Great White, *Carcharodon* (?).

The barracuda was *Sphyraena barracuda* the largest of the group. The Great White Shark is a tentative identification of a very large shark seen in the strait between Sandy Key and Salt Key on January 9th, 1944. This shark was estimated to be approximately 30 feet long. Another specimen seen in Hanover Sound on April 1st was probably of this species.

The barracuda of this region is much feared by the natives, more so than sharks, but simply because it can come into much shallower water than can a dangerously large shark.

CONDITIONS WHICH FAILED TO RELEASE AN ATTACK PATTERN

In this section, there are listed several occasions on which conditions were apparently ideal for a shark or barracuda attack upon a man in the water, but as no signs of hostility were noted, the releaser was absent. The quotations are from the log written up immediately after returning to shore.

January 22, 1944. Sandy Key, Bahamas. "Two sharks (8 feet and 5 feet) were within 20 feet but did not molest us. The smaller one came in our direction but turned off at about twenty feet. Sub-Lieut. ——— and I were together but had only one spear between us." These sharks swam around and inspected the swimmers from a distance of twenty feet. The big one turned head on with his tail moving jerkily from side to side and looked as if he was making

up his mind. The smaller one swam up for a closer inspection but, when the swimmers bunched up and held a spear toward him he sheared off. They swam slowly and steadily with their faces underwater watching the sharks and made no sudden moves. The sharks soon swam off behind a reef and were not seen again.

January 28, 1944. Hanover Sound, Bahamas. "A large barracuda came up to Capt. ——— and Flt. Sgt. ——— but did not molest them." These men were spear-fishing on a reef with forty others and were to one side of the main party. They did nothing but watch the barracuda as it swam around them and then returned to deep water. They were in about thirty feet of water and several hundred yards from shore.

January 13, 1944. Salt Key, Bahamas. "A large barracuda (5 feet) came very close to several of the unit today and followed into 2 feet of water but made no effort to attack." They withdrew cautiously ahead of it and it seemed only curious.

February 2, 1944. West end of Salt Key, Bahamas. "An 8-foot shark came up to within 6 feet of ——— when he was without a spear today. Four men were in the water quite a distance from the others and the shark had them rather worried. I ran the boat down to them and opened fire with a Sten-gun into the water over the shark. He made no effort to attack and I took the men aboard." It is very doubtful if the Sten-gun fire had any effect on the behavior of this shark as it was completely submerged and the noise and vibration of the boat's engine would drown out the sound and shock of the burst hitting the water.

April 20, 1944. North end of Sandy Key, Bahamas. The following experience is not comparable with the previous entries as the species involved is the harmless Nurse Shark (*Ginglymostoma*), but the entry will serve to llustrate two points. The first is the degree of confidence attained by members of the unit in dealing with large fish underwater, and the second is the amount of molestation even a very large shark of this species will endure without retaliation.

" ———, ——— and I found four large Nurse Sharks lying under ledges N. of Sandy Key today. They were about 8 feet long and weighed 200 pounds plus. I speared one through the gill-slit but the spear pulled out. It was just as well as I could never have held him. I then went down again to spear the second shark whose tail was the only part visible. We all thought he was much smaller than the first one, but when I got down to him and looked under the ledge I could not see his head at all. Instead of spearing him through the gill-slit as I should have, I could only reach his tail. I was then aware that he was very much bigger than he appeared from the surface. It was impossible to reach his head so I jabbed him lightly in the side to make him turn around. He did all right. His head came out within two feet of my face and was as broad between the eyes as my chest. He was a good 8 feet long and would weigh well over 200 pounds. He was attended by a pair of shark suckers (*Remora*). I did not bar his passage and he swam off rather leisurely. It would have been impossible to hold either of these sharks as they could easily tow a man. We also saw three barracuda, one

of whom seemed to be deformed as his body was bent so that he had the appearance of being hump-backed. They swam about as usual and opened and shut their jaws ominously when we chased them."

April 21, 1944. E. end of Rose Island, Bahamas. "Sub-Lieut. ——— reported a 6-foot shark, not a Nurse, came up to within 6 feet of him but did not molest him." He was spear-fishing on the reef alone.

In none of these cases were the men carrying speared fish, nor did they show fright by rapid panicky movement.

THE USE OF BLOOD AS A STIMULUS

An attempt was made to stimulate an attack behavior pattern by the use of blood. In these experiments a fishing cruiser was used from which baits were fished in the oil slick produced by dumping blood overboard.

In the first experiment it was not possible to obtain the desired quantity of blood. One gallon of fresh turtle blood was all that was available.

This was used in conjunction with suitable baits in the Tongue of the Ocean west of New Providence Island where sharks are very plentiful. No strikes were obtained in four hours fishing although two Brown Sharks were seen swimming at the surface about the oil slick.

A second attempt was made over the bar of Nassau harbor where sharks gather to feed on the city's refuse. Ten gallons of sheep blood and offal were used in this experiment but three hours fishing in the oil slick also failed to produce a strike.

These baits were not trolled through the oil slick but still-fished from the uptide side. There was therefore no movement of the bait.

It would appear from these experiments, which of course are far from conclusive, that blood alone is not sufficient to release the attack pattern, in shark or barracuda, to the pitch commonly believed to exist under these conditions.

THE EFFECT OF BLOOD AND VIOLENT MOVEMENT

An example of the effect of blood and violent movement upon a barracuda was observed on February 18, 1944. A four-foot barracuda had been seen daily for several months at the same reef and it had become so accustomed to the Unit that it paid no attention to forty men swimming and diving on its home reef. On the date mentioned the barracuda was swimming lazily about among the men who were fishing his reef and paying no attention to them, or they to him. Sub-Lieut. ——— located a fair sized Nurse Shark lying in a hole in the coral as is their habit during the day. He dived and speared it through the gill-slit and the shark went into a violent flurry with blood pouring from its torn gill. The spear pulled out during the flurry and the shark made for deep water. The barracuda, at the time of the attack on the shark, was about 100 feet away and on the other side of the reef. It is possible that it was high enough up to see over the reef but this is not certain. As soon as the shark went into it's flurry and the blood entered the water, all semblance of docility left the barracuda and it went at full speed for the wounded shark. They disappeared heading out for deep

water and the barracuda was not seen again that day on his usual location. However the same shark, identified by the wound in its gill, was found in a hole about a quarter of a mile away some hours later, so apparently it had little to fear from the barracuda.

An experiment to determine the effect of blood plus rapid movement was carried out in the Tongue of the Ocean where the first "blood alone" test had produced no results. The blood used in this experiment was fish blood from injured but still living fish and the movement was provided by the living fish attempting to get off the hook. Nine barracuda and one shark were taken in two hours, and five large sharks were hooked and lost using this method on subsequent occasions.

On April 21, 1944, at the east end of Rose Island, Bahamas, one of the men was spearfishing and had just speared a small sting-ray. The ray was flapping on the end of the spear and bleeding. A barracuda came up with a rush and seized the ray and jerked both ray and spear out of the man's hand and made off with both.

It would appear from the above that a combination of blood and rapid movement is a releaser of the attack behavior pattern.

THE EFFECT OF RAPID MOVEMENT WITHOUT BLOOD

In this category fall a number of experiences which befell the Unit.

On April 25, 1944, N. of Salt Key, Bahamas, there is the following entry in the log.

"The Unit encountered a 4-foot barracuda in murky water today and he was very excited and made several rushes at them. They waved knives in front of his face." (They did not have spears as they were on a long swim.) "The fins[1] seemed to attract his attention especially if they broke water and splashed. The barracuda followed into very shallow water. One of the men pulled his knife very fast when the barracuda came for him and cut himself on the side. He held the cut closed and swam ashore without getting much blood into the water, which probably saved him from being bitten. They seem definitely more dangerous in murky than clear water and seem more excited and fearless. The number of men had no appreciable effect upon his actions." This was a new area so presumably this fish had not seen forty men swimming about him before.

On January 22, 1944, north of Sandy Key, Bahamas, three of the Unit were out fishing. It was a very hot day and as the fishing was poor, they decided to drop the anchor outside the reef at Sandy Key for a swim. In entering the water from a boat or any high point wearing mask and fins, it is not possible to dive as the rush of water would pull off the mask. The normal procedure is to jump in feet first holding the mask in the hand and put it on in the water. Consequently, before the mask is adjusted, there is no visibility below. On this occasion, Sub-Lieut. ——— jumped in first and put his mask on in the water. His first glance below showed him an eight-foot shark just curving away from his legs in its first exploratory run. He raised his head and yelled, "There's a big shark here!" but it was too late

[1] Large rubber fins were worn on the feet to increase speed and endurance in the water.

for the other two to stop as they were both in the air. The resulting splash and flurry caused the shark to hesitate and, when the bubbles cleared and it saw there were three men where there was only one a minute before, it left. It is not known if it would have made the second run and attacked if the other two had not jumped in beside its intended victim, but the first run was made with mouth open and every sign of preparing to attack. There was no blood in the water here, but there was rapid movement and splashing.

On February 28, 1944, there was a demonstration of the reaction of sharks and other large fish to an explosion underwater sufficiently far enough away that they are not injured. On this date the Unit blew up portions of an old wreck on the west end of Salt Key with TNT blocks. Sub-Lieut. ——— and the author went down into the murk of the explosion to collect some dead fish directly after the explosion went off. There had been no large fish present before the explosion, and, as the wreck is situated on a barren flat with no cover for anything over a foot long, I am reasonably certain that there was nothing big within a considerable distance. Within five minutes of the explosion there were at least a dozen sharks up to 8 feet in length swimming through the murk eating the dead and stunned fish. ——— and the author watched their chance and got back to the ladders where they hung and watched the behavior of the sharks. A tuna, about 5 feet long, joined the feast for a short time but the dead fish were soon cleaned up by the sharks. The shock of the explosion immediately aroused the feeding pattern in these sharks as they arrived travelling very fast and at once began eating the fish which were both floating and on the bottom. This is not an area where explosions are common, so there can be no question of these sharks being "educated" that an explosion means a meal. However, they arrived at full speed and began feeding at once.

A final and most convincing demonstration of the effect on a barracuda of changing from an easy natural movement in the water to a labored jerky one, was given in a most unpleasant manner to one of the group. The entry in the log, written directly after the occurrence, is as follows:

"March 28, 1944, Salt Key, Bahamas. Capt. ——— had a very close call today. The Unit was swimming in formation out of the lagoon and around the east end of the island. . . . I was leading the column. Capt. ——— got a cramp and fell out . . . and started to swim ashore. He was about 200 yards out when the cramp became suddenly much more severe and he started to call for help. As soon as he started to flounder, a big barracuda (4 feet) came up to within a foot of his face and was circling about him and getting more and more excited. Capt. ———'s calls for help were heard by me at the head of the column, a good quarter of a mile away. Some of my men started for him but I called them back as there were others nearer. No. 2 Section were nearest and responded in a body. They found the barracuda, obviously much excited, flashing about Capt. ——— who could just barely keep himself afloat. They formed a circle about him and towed him ashore with the barracuda following all the way. It is apparent that the

fish knew he was in difficulties as there were forty men in the water and he paid not the slightest attention to anyone else. He was obviously working himself up to attack when ——— was reached. I consider this by long odds the closest call so far. ——— was badly shaken."

The author suspects that this barracuda was the one previously mentioned as being seen daily among the men when they were fishing that particular reef. If so, he had never shown signs of hostility before.

There was no blood present in this case, and until Capt. ——— got a cramp, there was no jerky rapid movement, and there were forty men in the water with the barracuda. As soon as one man began to move jerkily and rapidly, the attack pattern developed and, the author is convinced, would have been pressed home if timely aid in the form of ten husky spearmen had not arrived when they did.

CONCLUSIONS

These observations and the conclusions drawn from them, with the exception of the blood tests from the fishing cruiser, are not the result of carefully planned scientific experiments, but experiences which occurred in the routine training of a fighting unit. Their greatest value perhaps lies in the fact that they took place under completely natural conditions where the subjects behaved in accordance with their uninhibited behavior patterns, which is the ultimate object of any animal behavior study.

The conclusions to be drawn from the observations are as follows:

1. A man in the water, alone or in a group, acting quietly and smoothly did not release the attack pattern of either shark or barracuda.

2. Blood without movement did not release a feeding pattern in shark or barracuda in the Bahamas. This is the weakest part of the study and needs to be confirmed by more experimentation.

3. Fish blood and jerky, rapid movements released the attack pattern in both shark and barracuda.

4. Jerky, rapid movements alone released the attack pattern in both shark and barracuda.

From (2) above it would appear that taste or scent, alone or together, are not sufficient stimuli to release the attack pattern. However, from (3) we can assume that taste or smell or both need only movement added to release this attack pattern. From (4) we may conclude that tactile sense, the senses of hearing, and sight, are the primary releases and, from the explosion experiment, that hearing and/or tactile sense are sufficient to release the attack pattern.

As over 10,000 man hours were spent in the water with the subjects of this study, there is a fairly solid basis of actual experience behind these conclusions. It is not in any way suggested that these findings would hold in any other area, but it is a fact that no evidence to refute any of them was found in the other areas where the Unit operated in dangerous waters. These regions included the coasts of Ceylon and the Arakhan Coast of Burma.

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LEAD SHOT IN MINNESOTA WATERFOWL[1]

Vincent H. Reid

Minnesota Division of Game & Fish, St. Paul, Minnesota

INTRODUCTION

During the hunting season of 1941, a study was made to determine the frequency of occurrence of lead shot in the gizzards of waterfowl collected from lakes and marshes in Minnesota. Previous investigations indicate that the tendency of ducks to ingest lead shot during normal feeding operations may be a serious factor in the mortality of waterfowl. The present work, based upon a large number of gizzards collected from many areas, was an attempt to determine the seriousness of the lead shot problem in Minnesota.

[1] Contribution of Pittman-Robertson Project 11-R, Minnesota Division of Game & Fish. J. D. Smith initiated the study; C. H. Lostetter and L. A. Fried assisted with the examination of the gizzards.

REVIEW OF LITERATURE

Wetmore (1919) determined that six No. 6 lead shot are a lethal dose for waterfowl, and that the reaction to less than six ingested shot varied with the individual duck. He found that two or three shot killed some birds while others carried the same number of shot with no apparent ill effects. Wetmore also discovered that as the number of shot increased the resistance of the individual birds decreased.

Shillinger and Cottam (1937) reported that approximately 50 per cent of the ducks sent to the disease research laboratories of the Fish and Wildlife Service for autopsy were diagnosed as lead poisoning fatalities. They also found that lead shot occurred more frequently in diving ducks than in puddle ducks.

Cheatum and Benson (1945) found that after feeding mallard drakes one lead shot and then breeding them with normal females there was no apparent loss of fertility. They concluded, however, that with the obvious reduction in vitality of the poisoned waterfowl during the periods of lead absorption and of convalescence, it seemed certain that reproductive activity would be reduced to a minimum. Experiments conducted at the University of Minnesota (unpublished data) indicated that the fertility of eggs laid by a hen mallard which had ingested only one shot was reduced over 30 per cent.

SOURCE OF MATERIAL

Through the cooperation of 39 wardens located in the better waterfowl hunting areas tally cards were distributed to interested hunters who wished to have their duck gizzards analyzed. Tags were attached to the gizzards; species, number of birds represented, date, county, and name of lake, slough, or river were recorded on the tags by the hunters.

ANALYSIS OF DATA

The gizzards of 1,084 waterfowl, 970 from 16 identified species and 114 from undetermined species, collected in 62 localities scattered throughout the state were received and examined for lead (Table 1). The frequency of ducks containing ingested lead varied on the 62 areas from zero to 53 per cent. Ninety-nine of the 1,084 gizzards (9.1 per cent) contained lead shot. Four and eight-tenths per cent contained only one shot; 3.3 per cent contained from one to five lead pellets; and one per cent contained a lethal dose of six or more shots. Gizzards of five mallards, one pintail, and one canvasback contained lead pellets shot into them.

If the sample of waterfowl gizzards used in this study is a representative cross section of the ducks frequenting Minnesota, then approximately nine per cent of the birds—either local or migrating—are subjected to the deleterious effects of ingested lead, and at least one per cent may carry a lethal dose of ingested lead. These percentage figures may seem insignificantly small, but when viewed with respect to the annual waterfowl harvest in Minnesota alone, they assume greater significance. Minnesota duck hunters bag approximately 2,500,000 waterfowl annually. On the basis of the number of birds shot, 9 per cent, or 225,000, are carrying ingested lead. With the same percentage applied to the total number of ducks which visit the state, the number carrying ingested lead may be very great. In spite of well-directed experiments conducted in the past on the effects of lead poisoning on waterfowl, it is difficult to state what percentage of the ducks carrying less than a lethal dose will perish or have their physiological processes sufficiently interfered with so as to seriously affect their breeding potential. Duck production may indeed be seriously decreased if the percentage of ducks carrying ingested lead in the spring is the same as in the fall.

The ring-necked duck (*Nyroca collaris*) and the lesser scaup (*Nyroca affinis*) are more apt to contain lead shot than any other species of waterfowl (Table 1). The sample of greater scaup (*Nyroca marila*) is too small (two leaded gizzards) to warrant use. Of the 15 ring-necked ducks which contained lead

TABLE 1.—SUMMARY OF 1,084 WATERFOWL GIZZARDS EXAMINED FOR INGESTED LEAD SHOT

Species	No. Examined	One Shot		2–5 Shot		6+ Shot		Total Containing Shot	
		No.	%	No.	%	No.	%	No.	%
Mallard (*Anas platyrhynchos*)	229	17	*7.4*	8	*3.5*	5	*2.1*	30	*13.1*
Black Duck (*Anas rubripes*)	6	0	—	1	*16.6*	0	—	1	*16.6*
Pintail (*Dafila acuta*)	97	6	*6.2*	6	*6.2*	1	*1.0*	13	*13.4*
Blue-winged Teal (*Querquedula discors*)	217	2	*.9*	0	—	0	—	2	*0.9*
Green-winged Teal (*Nettion carolinense*)	9	0	—	0	—	0	—	0	—
Shoveller (*Spatula clypeata*)	37	1	*2.7*	0	—	0	—	1	*2.7*
Baldpate (*Mareca americana*)	11	0	—	0	—	0	—	0	—
Gadwell (*Chaulelasmus streperus*)	17	1	*5.9*	0	—	0	—	1	*5.9*
Lesser Scaup (*Nyroca affinis*)	75	7	*9.3*	4	*5.3*	0	—	11	*14.6*
Greater Scaup (*Nyroca marila*)	2	1	*50.0*	0	—	1	*50.0*	2	*100.0*
Ring-necked (*Nyroca collaris*)	35	4	*11.4*	9	*25.7*	2	*5.7*	15	*42.8*
Redhead (*Nyroca americana*)	26	1	*3.8*	2	*7.7*	0	—	3	*11.5*
Canvasback (*Nyroca valisineria*)	111	5	*4.5*	1	*.9*	0	—	6	*5.4*
Bufflehead (*Charitonetta albeola*)	2	0	—	0	—	0	—	0	—
Ruddy Duck (*Erismatura jamaicensis*)	22	0	—	0	—	1	*4.5*	1	*4.5*
Hooded Merganser (*Lophodytes cucullatus*)	2	0	—	0	—	0	—	0	—
Coot (*Fulica americana*)	72	1	*1.3*	1	*1.3*	0	—	2	*2.7*
Unknown	114	6	*5.2*	4	*3.5*	1	*.9*	11	*9.6*
Total	1,084	52	*4.8*	36	*3.3*	11	*.9*	99	*9.1*

shot, 12 were taken from one lake. This rules out the inclusive application of these percentage figures for this species, but it does suggest a possibility for the frequent occurrence of lead. Of all the diving ducks, the ring-necked is most similar to the puddle ducks in its food habits (Cottam, 1939). It prefers to feed in waters of intermediate depth rather than in deeper water with divers or in shallow water with puddle ducks. It seems probable that in this zone of intermediate water depth expended lead may tend to concentrate because of the common gunning practice of shooting from passes and from blinds located in shallow water. Because the ring-necked duck, with its under water feeding habits, uses this intermediate zone in feeding, it is more likely to ingest lead shot than other diving ducks.

Table 2 shows that diving ducks in Minnesota ingest more lead shot than surface feeders. This agrees with the

TABLE 2.—PERCENTAGE DISTRIBUTION OF INGESTED LEAD SHOT BY WATERFOWL GROUPS

Group	Number Examined	Ducks Containing Shot	
		Number	%
Puddle Ducks	623	48	*7.7*
Diving Ducks	275	38	*13.8*
Unknown	114	11	*9.6*
Coot	72	2	*2.7*
Total	**1,084**	**99**	*9.1*

work of Shillinger and Cottam (1937) who found that 9.53 per cent of the diving ducks they examined contained ingested lead shot. In the present study 13.8 per cent of the diving ducks contained lead pellets, while only 7.7 per cent of the surface feeders ingested lead shot. Two reasons are suggested for the greater occurrence of ingested lead in diving ducks than in the "tippers." Divers obtain most of their food in deeper water areas where the concentration of lead is greater. Puddle ducks usually feed in shallow water areas that contain less lead shot and frequently leave the water to feed in grain fields. On reason for the greater decline in the diving duck population over the puddle duck population in recent years may be due to the more frequent ingestion of lead by diving ducks.

An attempt was made in the present study to correlate the percentage frequency of leaded ducks with the time and place the birds were collected. During the early part of the season this provided a means of locating lakes which contained heavy deposits of lead. In addition it suggested that a greater percentage of the ducks shot the first two weeks of the season—local ducks—contained lead than those shot during successive two-week periods. Waterfowl taken during the first two-week period (Table 3) were from 56 different areas and constituted 78 per cent of all the ducks examined. This represents a fair sample of the duck areas in the state. Most of the ducks taken the first two weeks probably were produced locally. During the period November 13th to 27th, only 13 gizzards were received from five areas (Table 3). This is not an adequate sample from which to draw conclusions.

TABLE 3.—DISTRIBUTION OF DUCK GIZZARDS ON THE BASIS OF DATES COLLECTED

Date	No. of Gizzards	% of Total	No. of Areas	Ducks Containing Shot	
				Number	%
Oct. 1–7	741	*68.3*	46	59	*7.9*
Oct. 8–15	111	*10.7*	10	18	*16.2*
Oct. 16–22	69	*6.1*	8	8	*11.9*
Oct. 23–29	38	*2.7*	6	3	*3.5*
Oct. 30–Nov. 5	83	*7.6*	8	8	*10.1*
Nov. 6–12	29	*2.7*	10	2	*6.9*
Nov. 13–27	13	*1.2*	5	1	*7.6*
Totals	1,084	—	57	99	*9.1*

A condition of differential lead ingestion may exist between local and incoming ducks indicating that birds are obtaining more lead in local lakes than in the less intensively shot over Canadian and Western Lakes and marshes. Minnesota lakes, therefore, may be a greater potential source of danger of lead poisoning than Canadian lakes. This seems logical when it is recalled that Minnesota is one of the five leading states in the sale of duck stamps and that with its 10,000 lakes it has, for many years, been a paradise for ducks and duck hunters.

If Minnesota lakes contain more lead than Canadian and western lakes, a note of warning is forthcoming. Modern waterfowl hunters are invading these hitherto little shot over lakes and marshes in increasing numbers. Thus the areas in which ducks are exposed to expended lead shot is becoming correspondingly greater. Because hunters are now invading the major duck breeding grounds of Canada and the West, the adverse effects of lead ingestion on the duck population will become increasingly significant.

SUMMARY

1. The frequency of ingested lead shot in ducks from 62 areas in Minnesota varied from zero to 53 per cent.

2. One thousand eighty-four duck gizzards were examined of which 99, or 9.1 per cent, contained lead shot. Of the total, one per cent contained six or more lead pellets which is a lethal dose.

3. There is an apparent need for information concerning the survival and breeding potential of ducks carrying less than a lethal dose of ingested lead.

4. Diving ducks had ingested more lead shot than the puddle ducks. Since this fact is known to be true in all areas where ducks have been examined for lead, it may be one of the reasons for the greater decline in the diving duck population.

5. Minnesota lakes may be a more serious source of lead shot than Canadian and western lakes, because local ducks contained more ingested lead than migrating ducks.

6. Because modern waterfowl hunters are hunting Canadian and western lakes in greater numbers each year and because these areas contain a major portion of the waterfowl breeding range, the problem of lead poisoning may become increasingly significant.

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WOOD DUCK NESTING BOX USAGE IN CONNECTICUT

William John Frank

Litchfield-Morris Wildlife Sanctuary, Connecticut State Board of Fisheries and Game, Litchfield, Connecticut

Introduction

The purpose of this report is to present data showing what species of wildlife used wood duck nesting boxes in Connecticut, and the degree and manner in which the boxes were utilized. The study was conducted on the Litchfield-Morris Wildlife Sanctuary in west-central Connecticut, and was commenced in the early spring of 1941 and continued until November, 1946. From June, 1942, until December, 1945, the project was under the direction of Mr. M. Arnold of the Connecticut State Board of Fisheries and Game.

The Litchfield-Morris Sanctuary is a tract of some 4,000 acres, situated in the townships of Litchfield and Morris. Most of the area was formerly cultivated but has reverted, both naturally and artificially, until it is now about 85 per cent forested with stands in the younger age classes. Five small ponds and the greater part of the shore line of Bantam Lake are contained within the property. The Bantam River, a slow meandering stream averaging about 20 yards wide, flows for several miles through willow-dogwood thickets and hardwood swamps, to form the principal inlet, and the outlet, of Bantam Lake. During the early development of the Sanctuary, game propagation was emphasized and about 3,000 wood ducks (*Aix sponsa*) were reared and liberated from 1924 to 1936, inclusive. Since 1936, wood ducks, both adults and broods of young, have been relatively common on the ponds and streams during the summer.

Box Construction and Placement

The wood duck nesting boxes were of the type used by the Illinois Natural History Survey, and, except as noted, were constructed to specifications furnished by that organization. Due to an error in construction of the box covers, each consisted of a piece of pine, $1\times12\times16$ inches, with two small pieces each $1\frac{1}{2}\times\frac{1}{2}\times10$ inches, attached to the underside. The latter were in lieu of a piece, $1\times9\frac{1}{2}\times9\frac{1}{2}$ inches, recommended by the Illinois Survey. Considerable warping of the covers occurred and the hooks and screw eyes for attachment soon became valueless. To overcome this deficiency, a piece of wood, 1×6 inches, was nailed to the back of the box, extending 6 inches above the top and 6 inches below the bottom, so it could be nailed to a tree. The cover was attached by sliding the rear edge beneath a piece of wood, $1\times1\times10$ inches, which was nailed to the 1×6 about $\frac{3}{4}$-inch above the back of the box. A hook was attached to the underside of the cover, $3\frac{1}{2}$ inches from the front edge, and was inserted in a screw eye on the front of the box. These changes were considered improvements in the box construction as the erection of the boxes, and the removing and replacing of the covers, were facilitated.

The boxes were constructed of finished ¾-inch white pine, and were stained a dark brown. About three inches of sawdust were placed in the bottom of each box at the time it was erected. The boxes were attached to trees, 6 to 28 inches diameter-breast-high, and wherever possible the larger trees were selected. The height of the box entrance holes from the ground varied from 12 to 24 feet.

INSPECTIONS AND DATA

Inspections were made by visiting each box and recording the species which was using the box and the manner in which it had been, or was being, used. The criterion for considering a box as used depended upon whether or not animal sign, or an animal, was found in the box. Usually the boxes were cleaned of all debris and nesting material, except sawdust and wood duck nests, at each inspection so nesting material or other sign found in the box showed that it had been used since the last inspection. This procedure probably gives results which are conservative for it is possible that the boxes were used as temporary shelters or resting places and no sign left of such usage.

The category of the number of boxes used by the various species of wildlife, for a definite period of time, has been employed whenever possible to demonstrate the relative value of the boxes. When boxes were inspected frequently and an individual box had been used by but one animal between inspections, such a classification was satisfactory.

In some instances inspections were at comparatively infrequent intervals, and materials in a box showed that it had been used by more than one species of wildlife since it had been last inspected. Also, during the spring and early summer of 1944, and 1945, the boxes were inspected two or more times and records obtained have been combined to present usage for each of these periods. An individual box checked during an inspection period might have contained two or more squirrel leaf nests, or have been used by more than one species. The classification of number of boxes used would not present this information, so the number of records of use obtained during these periods has been employed. Under such a classification there is the possibility that an individual box, which had more than one usage record for the same species of wildlife during an inspection period, was used by the same individual who persisted on using the box despite the removal of any materials it had brought into it, such as in the case of gray squirrel leaf nests. There was no way of separating these individuals and each nest or sign noted at each inspection was considered a usage record, unless it was definitely known that the same animal had used the box, and this only occurred with nesting wood ducks and nests of gray squirrels containing immatures.

In March and April of 1941, 33 boxes were placed in a hardwood swamp adjoining a small pond, in five rows about 100 yards apart, and boxes were about 50 yards distant in the rows. These boxes were inspected June 27, 1941, and one box had been used as a nesting site by a wood duck. Usage by other species of wildlife was not recorded. Four additional boxes were placed in June, 1941, and the total of 37 boxes were inspected March 27, 1942. Ten, or 27 per cent, of the boxes

had been used during the nine month period, June 27, 1941 to March 27, 1942. Two, or five per cent, of the boxes were used by gray squirrels, and the other eight or 22 per cent, by wasps or hornets.

All but two of the 37 boxes were removed in March, 1942, and 13 were replaced, 40 to 80 yards apart, along the edges of two small ponds. The 15 boxes afield during the wood duck nesting season of 1942 were inspected in June, 1942, for wood duck usage, and no nests, or remains thereof, were found.

In the summer of 1942, 21 boxes were placed along the Bantam River inlet, making a total of 36 boxes afield. These were inspected in May, 1943, and 3, or 8 per cent, had been used by wood ducks. Data on usage by other species were not recorded, except one box used as a nesting site by a screech owl, and another occupied by an adult screech owl. In the early summer of 1943, 32 additional boxes were erected making a total of 68 boxes in the field. Sixty of these were inspected in October, 1943, and the data obtained represented usage for a period of about five months. Eight, or 13 per cent, of the boxes had been used as follows: gray squirrels—two boxes, wasps or hornets—two boxes, honey bees—two boxes, wood ducks—one box, and white-footed mice and hornets nest—one box.

Two more boxes were placed in the spring of 1944, making a total of 70 boxes afield. These were inspected in late March and early April of 1944, and each box was again inspected one to four times during the remainder of the spring and early summer. The inspections began April 28 and terminated July 7 during which period three of the boxes were removed. The usage data for the 70 boxes inspected in the spring and early summer of 1944 are presented in Table 1. Sixty of the boxes were last inspected in October, 1943, so the data show usage for a period of about 7 months.

Sixty of the 70 boxes afield had last been inspected in October, 1943, so data obtained thereon at the first spring inspection of 1944 were indicative of winter usage for a period of five months. Of the 60 boxes, 21, or 35 per cent, had been used as follows: 14 boxes or 23 per cent by gray squirrels; the remaining 12 per cent were used as follows: two by red squirrels, one by honey bees, one by owls, one by flying squirrels, and two by flying squirrels or white-footed mice.

All nesting material and debris, except sawdust, were removed from the boxes at the first spring inspection of 1944. Therefore the data obtained during the other spring and early summer inspections represent usage for a period of about 2.5 months. One box was removed at the first spring inspection in 1944 so only 69 boxes were afield during the spring and early summer, and two of these were removed during that period. The usage of the 69 boxes in the spring and early summer of 1944, exclusive of the first spring inspection, was as follows: Eleven, or 16 per cent, of the boxes were used and from these 11 boxes 14 records of usage were obtained. The usage by species included eight records of gray squirrels, two of red squirrels, three of wood ducks, and one of a flying squirrel or white-footed mouse nest.

There were 67 boxes in the field at the time of the first spring inspection in late

TABLE 1.—WOOD DUCK NESTING BOX USAGE FOR 1944, 1945, AND 1946

	1944		1945		1946					
	Spring & early summer (70 boxes)		Spring & early summer (67–61 boxes)		Mar. 27–Apr. 6 (61 boxes)		May 16–28 (60 boxes)		Nov. 5–12 (60 boxes)	
	No. Boxes	%	No. Boxes	%	No. Boxes	%	No. Boxes	%	No. Boxes	%
Unoccupied	44	*62.9*	22	*32.8*	43	*70.5*	51	*85.0*	26	*43.4*
Occupied	26	*37.1*	45	*67.2*	18	*29.5*	9	*15.0*	34	*56.6*
Species	No. of records	% Usage	No. of records	% Usage	No. of records	% Usage	No. of records	% Usage	No. of records	% Usage
Gray squirrel	22	*62.9*	32	*57.0*	11	*57.9*	6	*66.7*	23	*62.2*
Leaf nests	17		25		7		5		22	
Nest & young	2		3		—		—		—	
Nest & adult	3		3		4		1		—	
Dead adult	—		1		—		—		1	
Red Squirrel	4	*11.4*	1	*1.8*	1	*5.3*	—		—	
Nest	2		—		1					
Nest & young	1		—							
Nest & adult	1		1							
Flying squirrel	1	*2.9*	—		—		—		—	
White-footed mouse	—		1	*1.8*	3	*15.7*	—		6	*16.2*
Nest	—		1		2		—		3	
Nest & adult	—		—		—		—		3	
Dead adult	—		—		1		—			
Mouse or Flying squirrel nest	3	*8.5*					1	*11.1*	2	*5.4*
Owl	1	*2.9*	4	*7.2*	1	*5.3*	—		1	*2.7*
Pellets	1		2		1				—	
Nests	—		2		—				—	
Adult	—		—		—				1	
Wood duck nest	3	*8.5*	2	*3.6*	—		1	*11.1*	1	*2.7*
Wasps or hornets	—		14	*25.0*	2	*10.5*	1	*11.1*	2	*5.4*
Honey bees	1	*2.9*	2	*3.6*	1	*5.3*	—		2	*5.4*
Total	35	*100.0*	56	*100.0*	19	*100.0*	9	*100.0*	37	*100.0*

March and early April of 1945, and these boxes had last been inspected in the early summer of 1944. At the first spring inspection, 11 boxes were taken down, and 5 of these replaced at other locations, so for the wood duck nesting season there were 61 boxes afield. The boxes were inspected 2 to 5 times during the spring and early summer from March 28 to July 2. The records of usage during these inspections, inclusive of the first spring inspection, are presented in Table 1. These data show usage over a period of about one year.

The data obtained from the first spring inspection in 1945 represent about 9 months of usage. The first spring inspection of 1945 showed that 27, or 40 per cent of the boxes had been used as follows: Gray squirrels used 12 boxes or 18 per cent of the total number and of the remaining 22 per cent eight had been used by wasps and hornets, four by owls, one by bees, one by wood ducks, and one contained a nest probably belonging to a white-footed mouse.

All nesting material and debris, except sawdust, were removed from the boxes at the first spring inspection so the data, exclusive of the first spring inspection, represent usage for the spring and early summer, a period of about 3 months. These data showed 29 records of usage from 24 boxes occu-

pied. The usage records consisted of 20 for gray squirrels, one for red squirrels, one for honey bees, six for wasps or hornets, and one for wood ducks.

In 1946 there were 61 boxes afield. These were inspected twice in the spring and once in the fall. One of the spring inspections was made in late March and early April, the other in late May, and the fall inspection in November. At each of these inspections all nesting material and debris, except sawdust and wood duck nests, were removed. Only 60 boxes were included in the second and third inspections. The data obtained are presented in Table 1.

USAGE BY SPECIES

The following species of wildlife were found to have occupied the nesting boxes: gray squirrel (*Sciurus carolinensis leucotis*), red squirrel (*Tamiascirus hudsonicus loquax*), flying squirrel (*Glaucomys volans volans*), white-footed mouse (*Peromyscus leucopus noveboracensis*), wood duck (*Aix sponsa*), screech owl (*Otus asio asio*), saw-what owl (*Cryptoglaux acadica acadica*), honey bees (*Apis mellifica*), hornets (*Polistes* sp. and *Vespa* sp.) and wasps of the family *Sphecidae*. The extent and type of usage for each species will be presented separately.

GRAY SQUIRREL

The gray squirrel population on the sanctuary is probably the largest of any of the mammals, excluding the mice and shrews. In 1941 preliminary censuses of gray squirrels by leaf nest counts and spot-time counts, indicated a population of a squirrel to every two acres. (W. D. Fitzwater, 1942, "Progress Report of Squirrel Investigations on the Litchfield-Morris Wildlife Sanctuary, 1941–1942. MS. Connecticut State Board of Fisheries and Game.) The comparative abundance of this species, its habit of using cavities in trees as nesting sites as well as the construction of outside leaf nests, make it susceptible to the nesting boxes, and gray squirrels were the commonest occupant of the boxes. To substantiate this occupancy, a few statistics from various inspections will suffice. In the first spring inspection in April, 1944, of 60 boxes last inspected in November, 1943, gray squirrels had occupied 14, or 67 per cent of 21 boxes used. Eight, or 57 per cent of 14 boxes occupied in the spring and early summer of 1944, from April 1 to June 15, were used by gray squirrels. Of 61 boxes in the field in the spring and early summer of 1945, April 1 to June 21, 20 records of gray squirrel usage were obtained from a total of 29 usage records from 24 occupied boxes. From about May 28 to November 12, 1947 (5.5 months) 23 or 38 per cent of 60 boxes afield were used by gray squirrels and this was 62 per cent of all boxes used during that period. These data show that gray squirrels will use the boxes and on this sanctuary such usage exceeded that by any other species. The data are still more impressive as the boxes were not erected with the intent of gray squirrel occupancy but were placed in habitats believed favorable to wood ducks. If the boxes had been placed in the mature and over-mature hardwoods along the highways or in the oak-ridge forest cover type, both favorable gray squirrel habitats, the usage by gray squirrels would undoubtedly have been increased.

The primary use by gray squirrels

consisted of constructing leaf nests within the boxes. Evidently the boxes provided added shelter which encouraged the squirrels to build their nests inside the boxes rather than in the open crowns of the trees. Adult gray squirrels were found in leaf nests in the boxes on 11 occasions, and on three of these two squirrels were present simultaneously. Two squirrels were found in a box on April 2, 1946, April 6, 1945, and March 29, 1944—in the early spring. This socialistic tendency may be allied with the breeding season. The squirrels were reluctant to leave the boxes after the covers were removed, and sometimes had to be prodded. Adults were twice found asleep in the boxes and the noise of placing a ladder against the box and tree, and the removing of the box cover had not awakened them. Dead adults, or the remains thereof, were found in two of the boxes. Immature gray squirrels were found in five of the boxes and the data are presented in Table 2.

TABLE 2.—RECORDS OF IMMATURE GRAY SQUIRRELS IN WOOD DUCK NESTING BOXES

Date	Record
March 30, 1944	Two immature gray squirrels in box, practically hairless.
April 10, 1944	Three immature gray squirrels, 2 male and 1 female, in box. Estimated age of two weeks.
May 13, 1945	Four immature gray squirrels, 1 female and 3 males in box. Estimated age of 1 week. The box was last inspected May 2, 1945, so squirrels were born between the 2nd and 13th of May.
June 1, 1945	Immature gray squirrels in box, estimated age of 3 weeks. Box last inspected May 13, 1945, so they must have been born between May 13th and June 1st.
June 6, 1945	Four immature gray squirrels, about half-grown, in box. Box last inspected May 5, 1945, so they must have been born after that date. On June 19th the box was rechecked and one dead immature plus the entrails of another were in the box.

RED SQUIRREL

Comparatively few of the boxes were located in the dense coniferous cover to which the red squirrel is allied, so little usage by this species was noted. Of all the inspections, red squirrels, or their sign, were recorded but 6 times and one of these may have been the same squirrel. Twice red squirrels and their nests were found in boxes, and three records of other nests were obtained. Four immature red squirrels were found in a box on May 29, 1944. This box had last been inspected May 14, 1944, so the squirrels had been born between May 15 and May 29.

FLYING SQUIRREL

One positive record was obtained on this species and that consisted of a sight record of one leaving a box. The investigators were not sufficiently acquainted with the species to positively identify their nests, but 6 nests very probably belonged to this species.

WHITE-FOOTED MOUSE

The white-footed mouse was the only species of mouse known to use the boxes. Complete records of usage by mice were not taken prior to 1946 but sufficient

data were obtained that year to indicate their activity. The boxes were used as shelters in which nests were constructed. In 1946, 9 nests were recorded with mice being present in three of them. Of the three nests containing mice, two mice were present in each of two of the nests. Six of the 9 nests were found in November and the increased usage in the fall was likely due to the impending cold weather. In the fall of 1943 a bald faced hornet's nest containing six mice, was removed from one of the boxes.

WOOD DUCK

The project was initiated with the intent of providing nesting sites for wood duck, and, whereas the sites were provided, the usage thereof was slight. From the standpoint of increasing the carrying capacity of the sanctuary for wood ducks the project failed as a management practice, and it was only through the usage by other species, mainly gray squirrels, that the erection of the nesting boxes as a management practice could be considered feasible. A total of 274 boxes were in the field during the six wood duck nesting seasons and wood duck nests were found in but 12. The records showed that wood ducks did use the boxes and it is not believed that the infrequent use was due to the type of box construction. With more boxes better results might be expected but if the ratio of boxes used to boxes afield cannot be increased, the cost of the boxes and inspection would be prohibitive as a management measure.

To reduce the possibility of competition for occupancy of the boxes by other species of wildlife, an inspection was usually made in the spring before the wood duck nesting season and all debris and leaf nests were removed from the boxes. No evidence was found of competition for occupancy.

The data for the wood duck nests are presented in Table 3. Wood ducks were found incubating as early as April 9, and as late as June 6. There were 10 eggs present in a box on April 6, 1945, and on April 9 the female had begun incubation. Assuming that one egg was deposited each day, the female must have commenced nesting in late March. Most of the nesting occurred in April and May and this is probably average for the State of Connecticut. There was no indication of predation of the nesting ducks or their eggs, and all evidence led to the conclusion that the nests hatched successfully. In a few instances infertile unhatched eggs were found in nests in which the rest of the clutch had hatched. Increased data could have been obtained by visiting the nests more frequently but it was thought that such procedure might lead to the abandoning of the nests.

OWLS

Two species of owls, the saw-whet and the screech, used the boxes. Owl pellets were found in four of the boxes, adults were noted twice, and nests were found in three. On April 7, 1945, an owl nest, probably screech owl, was found which contained 3 eggs and 3 decapitated mice. A screech owl was seen peering from a box on December 18, 1942 and on April 13, 1943 an owl had begun to nest in the box as at least one egg had been deposited. There was no nest structure but the egg was laid on the sawdust in the box. The box

TABLE 3.—WOOD DUCK NESTING RECORDS OBTAINED FROM NESTING BOXES

Date	Record
June 27, 1941	Egg shells and down in box. All indications of a successful hatch.
May 11, 1943	A nesting wood duck in box. On October 10, 1943, box was again inspected and 3 unhatched eggs found plus shells of eggs that did hatch.
May 14, 1943	Egg shells and down present in box. All indications of a successful hatch.
May 14, 1943	Egg shells and down present in box. All indications of a successful hatch.
October 10, 1943	One unhatched egg found in box.
May 9, 1944	Female wood duck on nest. Box last inspected April 6th and no sign of nesting at that time, so nesting began between April 6th and May 9th. June 6th brood was gone and all indications of a successful hatch.
May 9, 1944	Female wood duck on nest. Box last inspected April 6th and no sign of nesting at that time, so nesting began between April 6th and May 9th. June 5th brood gone and one egg in box. All indications of a successful hatch.
May 18, 1944	Female wood duck on nest. No nest present April 10th when box was last inspected so nesting must have started between April 10th and May 18th. June 1st brood gone and all indications of a successful hatch.
April 6, 1945	Ten eggs in nest in a box. April 9, May 2, 7, 9, wood duck on nest. May 29th eggs had hatched and brood gone, and gray squirrel leaf nest begun over duck nest.
June 6, 1945	Wood duck on nest.
May 18, 1946	Wood duck on nest and egg shells noted so probably eggs were hatching. Box last inspected March 29th and no sign of nest at that time, so nesting began between March 29 and May 16. June 1st, eggs had hatched and brood gone.
November 6, 1946	Two unhatched wood duck eggs, shells and down in box. Box last inspected May 23, 1946, and no sign of nest at that time.

contained the adult and five young on May 13 and at that time another adult, probably the male, was seen in a box about 200 feet distant. The female could be handled readily as could an adult red phase screech owl found in a box on November 6, 1946. A third nest was found April 7, 1945, which contained an adult saw-whet owl incubating five eggs. The owls evidently used the boxes both as nesting sites and shelters.

HONEY BEES

Honey bees used seven of the boxes as hives and in all instances the boxes were filled with honey and comb. The usage by bees was slight for in 1946 of 69 boxes afield two were occupied by bees, and in 1945, of 68 boxes, two were so occupied.

WASPS AND HORNETS

The presence of wasps and hornets was not recorded at each of the inspections but sufficient data were obtained to show they ranked second to gray squirrels in usage. During the spring and early summer of 1945 each box was inspected 3 to 4 times, and of 56 records of usage, wasps and hornets contributed 14, or 25 per cent. In 1941–42 of 37 boxes afield for about a 9 month period, wasps or hornets had used 8, or 22 per cent.

Wasps or hornets used the boxes as shelters to construct their nests which

were of three types: the large conical paper bag nest of the bald-faced hornet, *Vespa* sp., the single layer, cellular type paper nest of the genus *Polistes*, and the long tubular mud nest of the family, *Sphecidae*.

SUMMARY AND CONCLUSIONS

A study of the usage of wood duck nesting boxes in Connecticut was conducted on the Litchfield-Morris Wildlife Sanctuary from 1941 to 1946, inclusive. The boxes were used by gray squirrels, red squirrels, flying squirrels, white-footed mice, wood ducks, saw-whet owls, screech owls, honey bees, wasps, and hornets. Gray squirrels and wasps or hornets were the most frequent occupants of the boxes and usage by other species was slight. As a management practice to increase the number of wood ducks on the sanctuary the boxes were a failure, despite the fact that wood ducks were a common summer resident.

UTILIZATION OF ARTIFICIAL NESTING SUBSTRATE BY DOVES AND ROBINS[1]

John B. Calhoun[2]

INTRODUCTION

It is a common observation that the robin (*Turdus migratorius*) nests in many sites on buildings. This habit has been exploited in the construction of artificial shelters, usually of wood, open on three sides, and covered by a roof, which are occasionally used. Doves (*Zenaidura macroura*) also will occasionally nest in man-made structures. McClure (1946) records eaves troughs, and girders under bridges as the most commonly observed location of such nests. However, it is a much more common trait of doves to utilize the old nests of other birds. Utilization of the nests of other birds by doves is reviewed by Nice (1922, p. 464).

Here are two birds which are found abundantly in the disturbed plant successional stages which are characteristic of most urban and farming regions of the central and eastern United States. Each will also utilize other sites than crotches in trees for the location of their nests. In the winter of 1945–46 the writer decided to construct some type of artificial nesting substrate which was amenable to mass production methods. After some consideration it was decided to utilize 90 pound roofing paper which was black on one side and coated with a crushed green rock-like material on the other side.

This roofing was cut into circles 9 inches in diameter. A V-shaped sector extending to the center of the circle with a 2 inch arc at the periphery of the circle was cut out. At the center a small circle, 1 inch in diameter was cut out. Then the two open ends, where the sector was removed, were over-lapped three

[1] Contribution from the Department of Zoology and Entomology, Ohio State University.

[2] Current address: Johns Hopkins University, 615 North Wolfe Street, Baltimore 5, Maryland.

inches and stapled together with a Bostich Model ½C* stapler. Four staples were sufficient to hold the cone together. This cone was approximately 7 inches in diameter with a depth of 2 inches and with a small opening at the apex of the cone which would allow rain to drain out. Half the cones were made with the black surface inside and the other half with the green surface inside.

EXPERIMENTAL AREA

A seventeen and a half acre tract directly behind the Botany and Zoology Building at the Ohio State University was selected as a convenient area in which to place the tar-paper cones. This area contained two experimental gardens for crop plants (Figure 1). Most of the remainder of the area was an arboretum of cultivated, native, and foreign shrubs and trees. The variety of plants was too great to make it of any value to attempt to correlate the distribution of nesting with the type of plant cover.

Figures 2 and 3 show the distribution of nesting sites of the robins and doves utilizing the study area. These delineate clearly enough the distribution of trees, etc. suitable for utilization as nesting sites. Over the area the cones were placed wherever a fork or crotch was found suitable for attaching them. Three to five roofing nails were sufficient to fasten a cone securely. The cones could be bent to fit the angle of the fork or crotch. Most of the cones were placed at levels between eight and eleven feet. As seen in Figure 1 cones with the green surface inside and with the black surface inside were approximately equally distributed over the study area. Fifty-nine cones had the black surface inside and 62 the green surface inside. These were placed during the third week in March 1946. Thereafter, a survey was made of the cones each week through June. In addition, every tree in the area was checked once every two weeks for nests not occurring in the cones. Trips at irregular intervals were made during July and August.

RESULTS

Robins began using the cones shortly after they were placed but had nearly quit using them by early in June. Doves on the other hand, were slower to utilize the cones, but maintained a greater intensity of utilization of cones much later in the season. No robins used cones during July or August. The last dove using a cone fledged the young on August 31. By taking into consideration the dates of duration of a nesting attempt it was possible to make a fair estimate of the number of nesting pairs of robins and doves, and to outline their minimal nesting territories. These are shown in Figures 2 and 3.

Fourteen of the 24 pairs of robins were involved in the 24 utilizations of cones as a nesting substrate (Figure 2). However, only 7 pairs used them successfully. As shown in Table 1, there were three times as many unsuccessful nesting attempts by robins in cones as there were successful attempts. Better success was noted for nests not in cones, that is, those in trees, bushes, and vines. Twenty-four of the 32 recorded successful nestings were not in cones. There were 24 unsuccessful nests not in cones.

A similar situation may have existed with the doves, but this was impossible

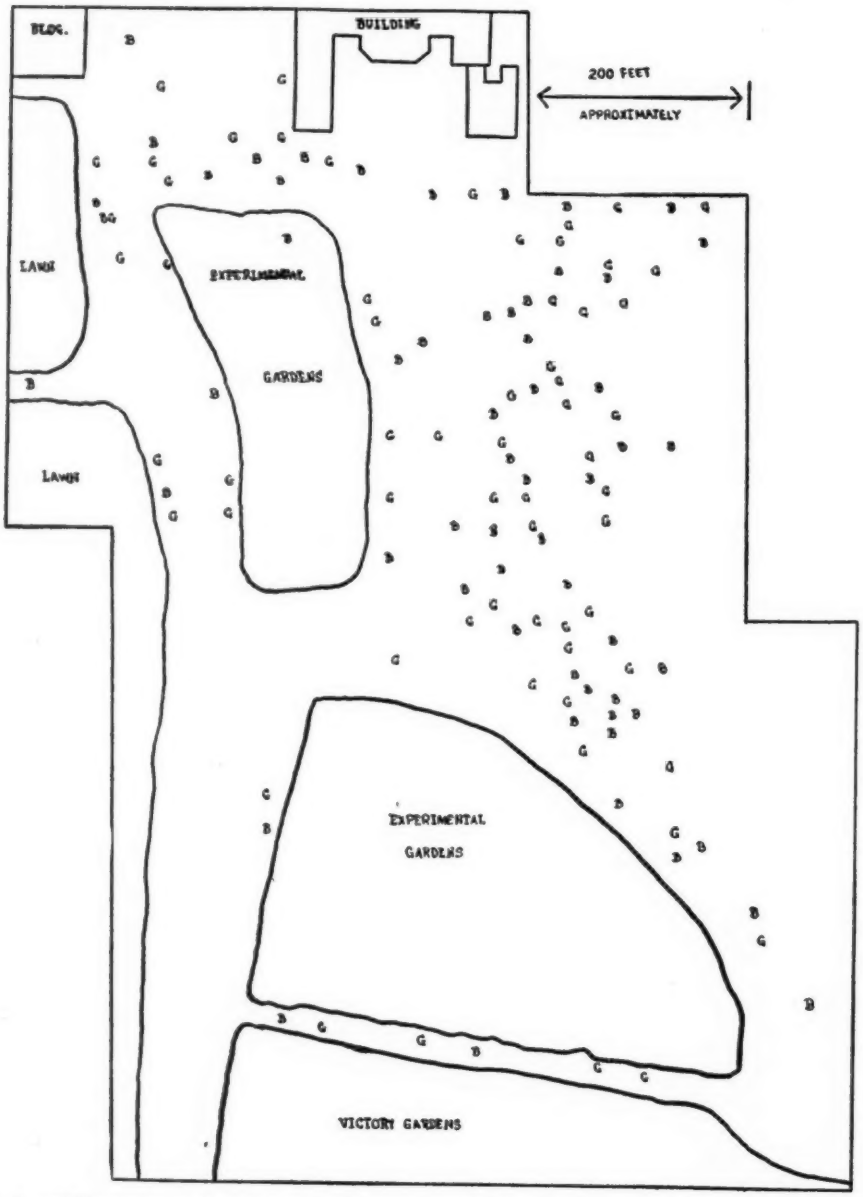

FIG. 1.—17½ acre experimental area. G's represent sites where cones with green surface inside were placed. B's represent sites where cones with black surface inside were placed.

to determine since it was difficult to locate all nests, not in cones, which were started and also abandoned between survey trips. This was not a problem with the robins since their much sturdier nests usually remained in place.

TABLE 1.—NESTINGS IN CONES

Surface Inside	Successful		Unsuccessful*	
	Robin	Dove	Robin	Dove
Green	4	5	12	5
Black	4	7	4	14

* Included in unsuccessful nesting attempts are those cones where the nests were built, but never used to the knowledge of the writer or where the eggs or young were destroyed. Two nesting attempts by doves in cones became unsuccessful just before the young were to have fledged, but are recorded as successful in the above table. One was in a cone with the green surface inside and the other with the black.

Of all successful nesting attempts by doves 12 were in cones and 11 were in other locations. Eleven of the 13 pairs of doves in the area used the cones. Unsuccessful nesting attempts (which had proceeded as far as egg laying) occurred 12 times in cones and 5 times in trees. Most nest failures occurred within a few days of laying of the eggs. Since nests in trees were surveyed only half as often as those in cones there probably were several nest failures that were overlooked.

If the unsuccessful and successful nestings in cones are lumped together and the two species compared in their choice of cone-surface by the Chi square method, there is a χ^2 value of 3.8 with a probability of 0.05. The even distribution of the successful nestings, however, seems to indicate no choice in surface. The major contribution toward the significance of the χ^2 of the lumped data actually comes from the unsuccessful nesting attempts (Table 1). If these alone are analyzed, the χ^2 value is 6.4 with a probability of less than 0.02.

These are not necessarily contradictory results. It was noted that the greater number of unsuccessful attempts at nesting in cones were in those cones in the most exposed sites. Most of the exposed sites used by doves were black cones and most of the exposed sites used by robins were green cones. By the time predation had taken its toll of these nesting attempts it balanced the number of cones of each surface type in which there were successful nesting attempts. These data are purely exploratory and need to be confirmed by studies on a more extensive scale.

Predation causes of unsuccessful nesting in order of importance were by screech owls 9, blue jays 4, Norway rats 2, squirrels 3, cat 1, unknown 17.

McClure (1942, 1946), Nice (1922), and Pearson and Moore (1939) have found nesting failures to range between 40 and 60 per cent for doves. The latter of these authors (p. 472) concludes that there is "No practical means of reducing losses of nests and eggs . . . ." Certainly the data of the present study are not sufficient to state that these artificial cones will lessen nesting failures, although nests in cones are less likely to fall out than in most other localities. From his experience in this study the writer makes the following recommendations to other workers who may wish to use this technique in attempting to reduce nesting mortality among doves. Place all cones with the black surface inside. Particular care must be taken in attaching the cones. The best success will be obtained by placing cones in forks that are not a part of the main trunk of the tree. Protection of the cone by closely overhanging limbs and leaves is a deterrent to predators.

These artificial nesting substrata may be a useful tool in studying behavior

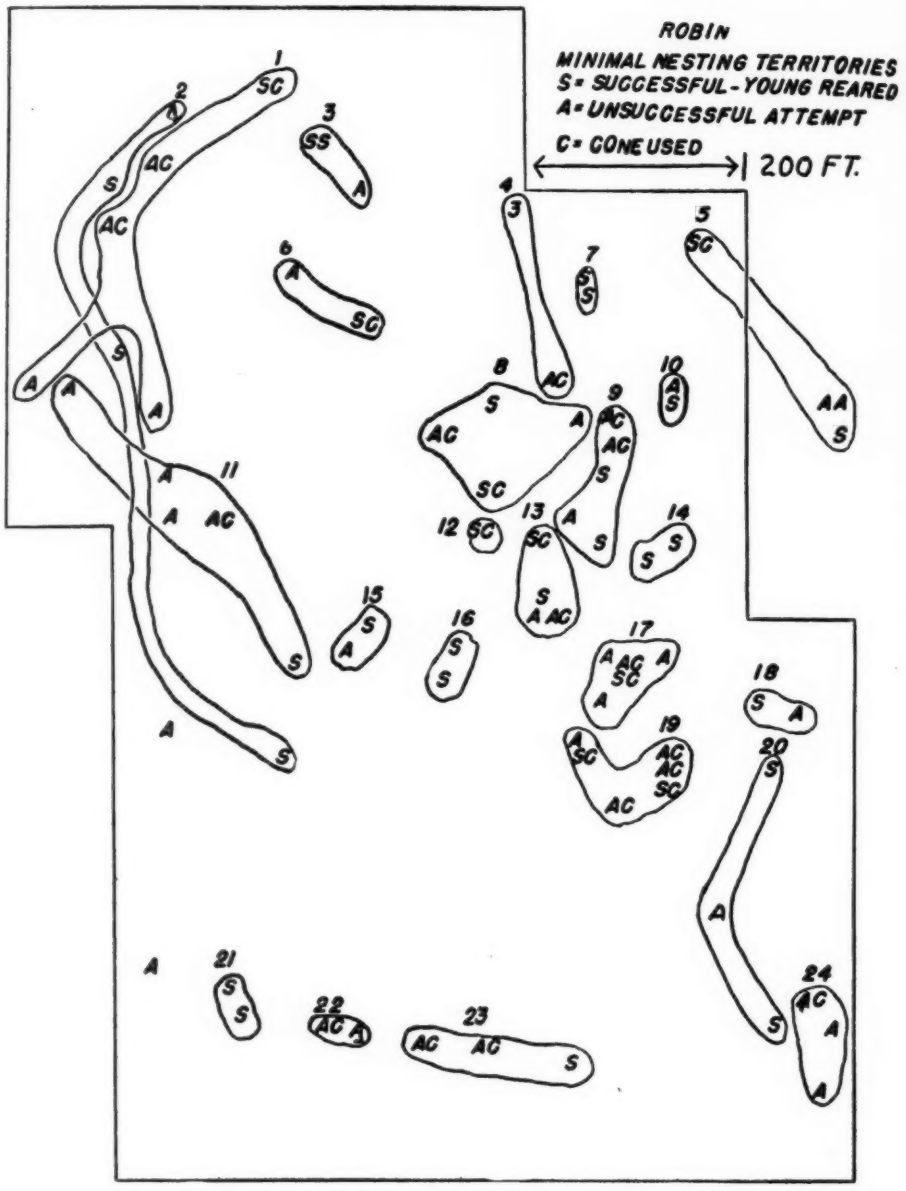

FIG. 2.—Minimal nesting territories of robins.

patterns in doves since they serve as a focal point of attraction during the period of initiation of the nesting cycle. On three occasions a pair of doves was noted perched on opposite sides of a cone which as yet contained no nesting

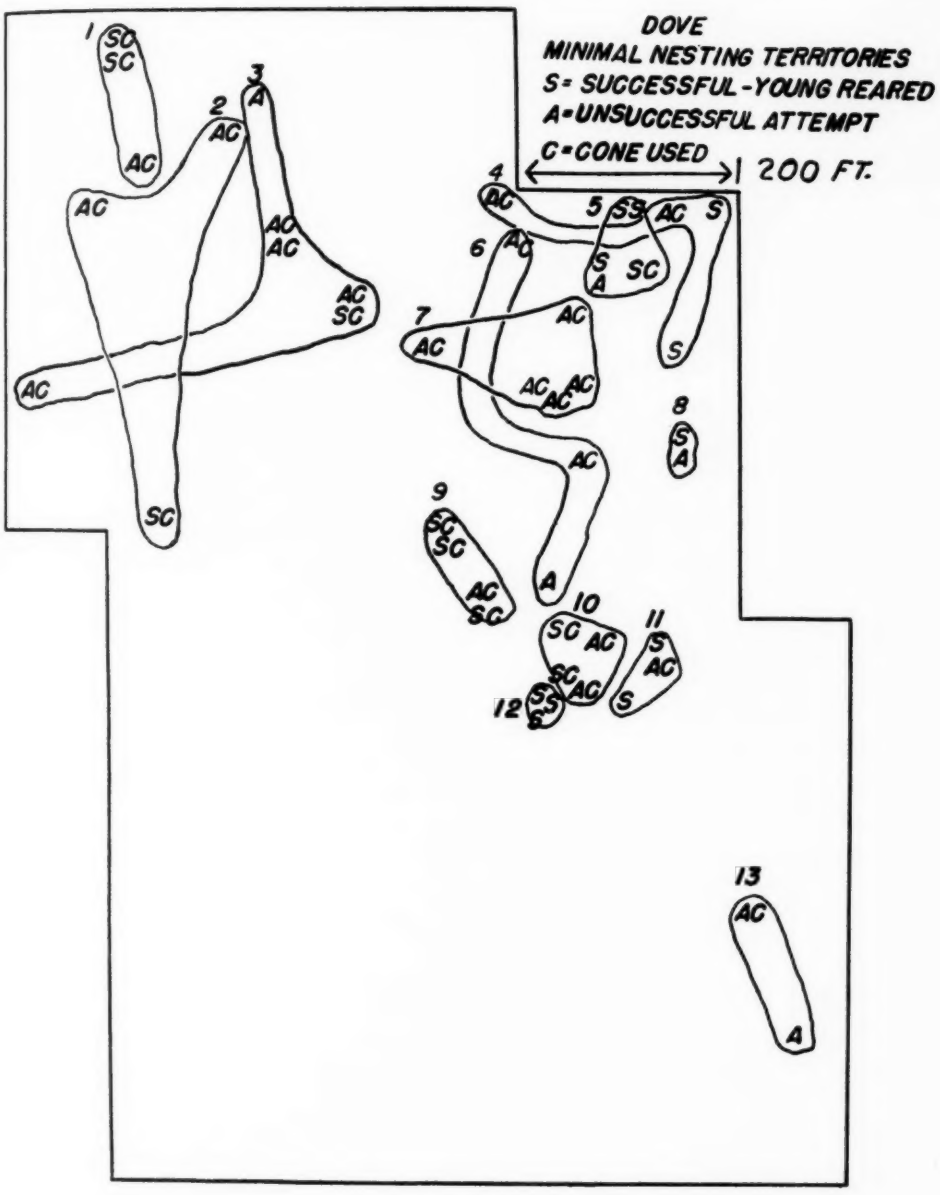

FIG. 3.—Minimal nesting territories of doves.

material. In each case a nest was constructed before the end of that day. The diameter of the cones is such that a parent and two young ready to fledge may sit side by side in the nest. No attempt was made by the writer to

follow a nesting from the period of nest construction through fledging of the young.

SUMMARY

1. Artificial nesting substrata for doves and robins were constructed in the form of cones from 90 pound roofing paper. These were nailed to suitable crotches and forks of trees.

2. Fifty-nine cones had the green crushed stone surface inside, while 62 had the black tar surface inside.

3. One-half of the robins in the area used the cones at some time, but only $\frac{1}{4}$ of such attempts was successful, whereas $\frac{1}{2}$ of the nesting attempts not in cones was successful.

4. Practically all doves in the area used the cones at some time but only $\frac{1}{3}$ of these attempts was successful.

5. Robins appear to prefer cones with the green surface inside, whereas doves seem to prefer cones with the black surface inside.

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RABIES IN THE WILD[1]

H. T. Gier

Zoology Department, Kansas State College, Manhattan, Kansas

In conjunction with an attempt to analyze the seriousness of and complications arising from the recent epizootic of rabies in foxes (*Urocyon cinereoargenteus* and *Vulpes fulva*) in Ohio, a review was made of similar outbreaks in the past and in other regions of the United States at the present time. The more important and interesting facts accumulated concerning rabies in wild animals by review of the literature, correspondence with contemporary workers and original work are recorded for use by others in the field of wildlife management. The occurrence of rabies in dogs and the transmission of the disease from dogs to man and domestic animals has been recognized and widely publicized for centuries. The disease has occurred in all parts of the world and still is too prevalent in all but a few countries in which adequate steps have been

[1] Contribution number *260* from the Department of Zoology, Kansas State College.

This study was made possible by a grant from the Athens (Ohio) Chapter of the Izaak Walton League of America, and by the facilities provided by Ohio University. Special acknowledgment is gratefully given to my assistants, Messrs. Larry Gale, Arthur Pickens, and Gilbert Smith, for aid in accumulation and analysis of the materials, and to the Health Commissioners, Boards of County Commissioners, Game Protectors, sportsmen, and others who so willingly cooperated throughout the study.

taken to eliminate it (Mohler, 1923). Symptoms of rabies in man, dogs, and domestic animals are well known, and are given routinely in veterinary and medical texts. Prevention, in the form of a vaccine, has been used since Pasteur's time, and slowly but surely improved forms of the vaccine are being produced, until at present dogs, horses, cattle and hogs may be immunized with a single inoculation, if it is given before exposure, or by at most three inoculations if the exposure occurs before vaccination (Eichhorn, 1928; Kelser, 1930; Lockhart, 1947; Corwin and Stice, 1947). Humans, however, are still regularly immunized, after exposure, by fourteen abdominal injections of the vaccine (Eli Lilly Co., 1945).

OCCURRENCE OF RABIES IN WILD ANIMALS

Rabies in wild animals has been sporadic, and although long recognized, apparently has not often occurred in epizootic proportions. In this country, there have been only a few such major cases: there was an outbreak of rabies in Massachusetts in 1812 that nearly eliminated the foxes in a large portion of the state (Thatcher, 1812); there were serious epizootics of skunk rabies in Kansas in 1875, and in Arizona from 1907 to 1910; and of coyote rabies on the west coast in 1915–16, and in New Mexico in 1943 (Johnson, 1945). Young and Goldman (1944) designated rabies as a very important factor involved in the extirpation of timber wolves from the southern part of their former range in Eastern North America. Beginning in 1890, rabies killed practically all the foxes in Baldwin and Mobile counties of Alabama (Wilkinson, 1893–94). Other epizootics of rabies in foxes have been reported in Maine in 1934, Massachusetts in 1936 (Schoening, 1942) and Wisconsin in 1938 (Guilford, 1938) previous to the present scourge in the Appalachian Plateau, which seems to be spreading and increasing in intensity. Johnson (1945) reported, in considerable detail, the extended fox rabies epizootic in Georgia and Alabama which began in 1940 and which appears in new places even before an older area of infection can be cleared up. Dr. Johnson, of the Rockefeller Foundation, and Dr. L. E. Starr, Public Health Veterinarian, State of Georgia, in personal communications state that the epizootic in Alabama and Georgia shows no signs of abatement. Compton (1943) reported an outbreak of rabies in foxes in Chautaqua County, New York, which Dr. A. Zeissig (1947) of the New York Department of Health informed me had died out of its own accord. Dr. Zeissig added that there was a new outbreak in Central New York which continues to spread. Dr. James H. Steele, Chief of the Veterinary Public Health Section, U. S. Public Health Service, stated in a letter dated April 10, 1947, "The fox rabies problem has become increasingly serious during the last four years in the Appalachian area of Eastern United States. Fox rabies at present extends from North Central New York, the length of the Appalachian range to Northwestern Georgia, westward across Alabama, Mississippi, Louisiana, into East Texas."

The numbers of foxes involved in the present epizootic is impossible to determine but Compton (1943) stated that during the early part of the outbreak in New York, a lively illegal, out-of-season

traffic of fox pelts occurred; that enough foxes (mostly *V. fulva*) were found to be rabies positive by laboratory tests to give a solid basis for clinical diagnosis in the field, and that many foxes were found in the woods, apparently killed by rabies. Johnson (1945) reported that early in the outbreak in Georgia, of 419 (mostly *U. cinereoargenteus*) foxes that were tested in the laboratory, 159 were determined to have rabies; that during the outbreak in northwestern Georgia in 1942, there were reported 355 cases of fox rabies, mostly without laboratory tests; and that in the last three months of 1942, there were 103 cases of fox rabies in Mobile and Washington Counties, Alabama. Dr. Starr wrote that, "During the year 1946, 4,377 foxes were known to have been destroyed or died of rabies; 476 fox heads were submitted to our various laboratories; 267 of these were positive. In addition to these, 500 clinical cases were observed which were diagnosed in the field." According to Garlough (1945), in Clarke County, Alabama during 3½ months in 1944, 1,188 foxes were taken in an area of 1,216 square miles in an effort to suppress an epizootic of fox rabies. It is not fair to assume that any large proportion of either the 4,377 or the 1,188 actually had rabies, as most of them were destroyed as a means of blocking further spread of the disease. No other sets of specific numbers are available, but these cases are enough to indicate that a very high incidence of rabies is possible in foxes.

Transmission of rabies from foxes to other animals is even less determinable than are the numbers involved. Starr (1947) wrote, "During the year 1946, 106 people in Georgia were bitten by rabid foxes and had to take treatment.—During the year we had reports from the field to the effect that 864 cattle, 151 horses and mules, 131 hogs, and 16 goats and other animals have died of rabies; a total value of $138,678.75. This figure is likewise very incomplete because only a fraction of the actual number that died has been reported. We are of the opinion that most of the losses are due to rabid foxes although this cannot be supported by actual figures since most of the exposures occur at night—dog rabies in this area has given us very little concern." Johnson (1945) listed specifically 54 cases of foxes biting humans, and 153 deaths in livestock from rabies and indicated that there had been many more. Dr. Zeissig wrote of the present outbreak in Central New York, "In this area, for instance, 432 head of cattle were lost during the 1946 grazing season. We have managed to keep the number of dog rabies in this area down to a very small number through the procedure of vaccinating a high percentage of the dog population. There is no doubt that in this area the dominant source of infection is the fox." Garlough (1945) reported: "During 1944 in 12 counties and parishes of Louisiana, Mississippi, and Arkansas, in which rabies was present among foxes, 405 domestic animals, valued at $28,295, were bitten and died. Ninety-eight people were bitten and took the Pasteur treatment." Apparently there was no attempt in this case to separate effects of rabies in dogs from those due directly to foxes.

So far as can be determined from available records and reports, there have been few human deaths from rabies that were traceable to foxes

during the present outbreak. Two deaths from rabies resulting from fox bites were reported in Alabama and South Carolina (Johnson, 1945). Undoubtedly hundreds of pelts from rabid foxes have been handled by trappers and fur dealers, with no ill effects to the handlers. It would appear, then, that the pelts are not seriously contaminated, and that the possibility of contracting rabies from the pelts is negligible although such possibility cannot be ruled out completely.

Occurrence of rabies in other wild animals is not so common. In addition to those epizootics mentioned in the historical review, rabies now occurs in the coyotes of the Imperial Valley, and there were three cases of rabies in bobcats during April, 1947, in Harden Springs, and Palm Springs, California: one of these bobcats attacked a child (Johnson, 1947). Starr (1947) reported three cases of rabies (by laboratory tests) in bobcats in Georgia during the present epizootic. One of these severely mauled several dogs and two cows before it was killed. Skunks seem to be very susceptible to the disease, and are involved in nearly every rabies epizootic (Johnson, 1945). Mountain lions, raccoon, and opossum have been suspected of having rabies, but the disease apparently does not become epizootic in these animals, so usually does not seriously affect the population.

DIAGNOSIS OF RABIES IN FOXES

Diagnosis of rabies in foxes, both *Urocyon* and *Vulpes*, is considerably simplified by the exaggeration of the change in the disposition of the animal commonly noted as an early symptom in dogs (Reitz, 1947). Foxes suffering from rabies lose their fear of man and his machines, dogs, horses, and other foxes. They roam abroad in daylight, frequently highways, barnyards, and open fields. They may proceed with the business-like trot of a rabid dog, or they may wander aimlessly about, going nowhere in particular, and paying little attention to anything that goes on around them. They may, especially in the early stages of the disease, attack without provocation, fight cunningly and viciously even a pack of dogs or a well-armed man; and frequently escape after inflicting severe injuries on their adversaries. During the later stages, however, they usually refuse to run from man or dog, and may be killed with a pitchfork, hoe, or light club, or fall victim to the prowess of a docile farm dog. They consistently refuse to sidestep danger, and are rather frequently run down by cars. On each of several occasions, a rabid fox has been killed while quietly watching the farmyard activities from a vantage point that did not conceal him. On other occasions, the rabid fox moved quietly into the barnyard to play or fight with the dog, or possibly to chase chickens, often as if in a playful mood.

Rabid foxes seem to be strongly attracted to farm buildings. Occasionally one enters a house. Once inside, they may or may not attack the inhabitants. Frequently, rabid foxes are found in stables or outbuildings, commonly asleep under the manger or other protected places, off the ground, as if seeking relief from moisture and air currents. They may or may not bite the animals in the stable. Division of rabies of wild foxes into "dumb" and "furious" types seems to be not too applicable. Most of

the cases, at least as observed in Ohio, begin with a period of extra cunning and viciousness connected with a loss of fear of man and dogs. There seems to be a progressive loss of viciousness, cunning, and fear as the disease progresses until the rabid animal is extremely meek before the paralysis stage begins. As with dogs, the disease terminates fatally by paralysis, with the jaw muscles usually the first to become paralyzed. Frothing at the mouth and the tendencies to snap at everything and to eat undigestible materials seem to be lacking.

Careful comparison of the stomach contents of 28 foxes positive for Negri bodies, failed to show any significant differences in the type of food ingested by rabid and by normal foxes. Four of the stomachs were completely empty; 12 contained chicken, mostly feathers and feet; 9 contained hog bristles and some meat, apparently scraps from the farm butchering; 15 had mice, and two of these had also each eaten a mole; four had opossum; six had bird other than chicken; only one had any rabbit, and that was only a small clump of hair; seven contained corn, of which three had nine grams or more per stomach; three had paper, of which bread wrapper and filter pad from a milk strainer were the only items of any bulk. This shows a definite trend in behavior from a rabbit catcher to a scavenger with a great increase in the utilization of items of some food value that are regularly to be found around the farm buildings. Of the "undigestible materials," there was a total of 48 grams in 12 stomachs, composed of: straw in four; leaves and twigs in 3; a small cinder in one; two pebbles in one; rotten wood fiber (8 grams) in one; burlap (8 grams) in one; and finely broken shale and coal (13 grams) in one. These items are of the same nature and nearly the same occurrence as is regularly found in "normal" foxes in this same region (Gale and Gier, unpublished data).

Regularly, the colon of positive foxes was void of food and extended with gas. Normal foxes *usually* have a considerable accumulation of faecal material in the colon and rectum. The small intestine of rabid foxes usually contained little material of any sort except the normal complement of worms, with a viscid mucus around them. This condition of full stomach and empty intestine, along with a reduced average weight (8.5 lb. average for 20 foxes, against a normal average of 9.5 lb.) indicates that shortly after the onset of the disease the fox holes up for two or three days, then comes out and feeds again after the symptoms have subsided before the final paralysis renders him completely helpless. Most of the rabid foxes encountered in Ohio evaded capture during the early stages of the disease, and were killed after what would probably have been their last meal anyway.

The only conclusive diagnosis of rabies in foxes, as in other animals, is by laboratory methods: i.e., either by animal inoculation, or by microscopic examination of the brain, or both. Production of rabies in experimental animals (usually mice) by inoculation with saliva or brain of the suspected animal is positive proof of rabies, and is near 98 per cent certain when conducted properly (Webster, 1942). However, this method is expensive both in experimental animals and in time.

Routinely, the test is made by microscopic examination of stained preparations of Ammon's horn (of the cerebrum) and of the cerebellar cortex. The presence of Negri bodies in any of the brain cells is considered as positive proof of rabies. Although Negri bodies are not always demonstrable, especially in the early stages of the disease, there is about a 95 per cent correlation between the microscopic test and the test by animal inoculation (Webster, 1942).

Clinical diagnosis of rabies in foxes, as in dogs, is complicated by similarity of some symptoms of rabies with conditions induced especially by worms and by distemper. The high efficiency of field men in making the diagnosis, however, is attested by the results in Alabama and Georgia (Johnson, 1945), and in New York (Compton, 1943) as well as by the original work reported in this paper. It is probable that an experienced man can be over 80 per cent accurate in diagnosis of fox rabies without the aid of laboratory tests.

RABIES IN OHIO FOXES

It is extremely difficult to determine how long rabies have been enzootic in the foxes of Ohio. The Laboratory of the Ohio Department of Health reported positive findings of rabies in foxes (species not designated) as follows 1941, 9; 1942, 6; 1943, 10; 1944, 5; 1945, 16; 1946, 71; and 1947, to June 1, 48 (Ey, 1947). There were rumors of rabid foxes in southeastern Ohio in 1938 and 1939, although definite evidence is lacking. The increase in the numbers of positive findings in foxes for 1945 and 1946 was accompanied by a less marked increase in positives in dogs, cats and cattle. These numbers are not indicative of the actual number of rabies cases in the state, but do show the trends, as it has become the practice for health authorities to send to the laboratory only those animals that are known to have exposed humans or domestic animals. Every attempt to determine the actual time and rate of increase in fox rabies in Ohio has met with an astounding lack of records.

Questionnaires sent in April, 1946, to the Departments of Health and to the County Commissioners of fifteen counties in southeastern Ohio where fox rabies was known to exist, brought replies from six counties with indications only from Muskingum, Perry, and Washington Counties that there was an unusual number of rabid foxes. Similar questionnaires in April, 1947, to 25 counties brought replies from fourteen counties with concrete evidence of fox rabies in nine counties, varying from three determined positive by the State Laboratory to a *guess* of 1,200 on one extreme, and a carefully marked map showing exact locations of 46 cases of fox rabies on the other extreme. The results are shown as nearly as can be determined in Table 1.

During the winter and spring of 1946–47, foxes were obtained from Athens and Meigs Counties for completion of studies on reproduction, foods, and parasites. Complete case histories were kept on each fox that was brought in, and all suspicious animals were checked for rabies by microscopic examination of smear preparations of Ammon's horn and cerebellar cortex. Of 50 foxes checked, 40 (6 reds, 34 grays) were positive for rabies, the more interesting of which are listed in Table 2. Of those not listed, several were found

dead, and several were killed under very "normal" circumstances for foxes. On four occasions, two rabid foxes were killed together, evidently hunting, or at least travelling in company. Several others were killed in barns, and at least four entered homes, three through windows. There are several newspaper reports of foxes attacking people: usually the fox slipped up behind the person and grabbed the hand; sometimes they attacked directly, biting and clawing wherever they could.

As nearly as can be determined, the present epizootic of rabies in foxes in Ohio began in Belmont, Muskingum, Fairfield and Pickaway Counties in early 1945, and spread by mid-summer to Harrison, Morgan and Washington Counties. The numbers of foxes involved was not much greater than usual. By November, 1945, a few cases of fox rabies had been rumored in Athens County and in most of the other counties of the unglaciated hill section of Ohio. In 1946, the epizootic reached a peak in Washington and Morgan, and possibly also in Noble, Monroe and Belmont Counties. The number of cases rapidly increased in Muskingum, Athens, Meigs, Gallia and Jackson Counties in late 1946 and early 1947, reaching peak frequency apparently by February or March, 1947, in most of these counties. Every county in Ohio from Trumbull, Fairfield and Ross Counties to the Ohio River has laboratory positive cases of rabies in 1945, 1946, or 1947. The epizootic seems to be subsiding somewhat in the northern and western fringe of counties listed. There has been an increase in rabies in West Virginia since early 1946, but no numerical study has been made. Reitz (1947) reported on the examination of 14 foxes from northern West Virginia, which showed clinical symptoms of rabies. Ten of these foxes were positive for Negri bodies.

TABLE 1.—INCIDENCE OF RABIES IN SOUTHEASTERN OHIO, 1946*

County	Rabid Dogs		Rabid Foxes				People Requiring Rabies Treatment	Livestock Loss		Foxes Bounties Paid
	Lab. Test	Report	Laboratory Test† 1945	1946	1947	Report		Cattle	Horses	
Muskingum	14	43	3	12	12	21	39	5	1	850
Guernsey	2	6	0	1	1	3	9	high		700
Perry	7	53	1	1	0	70	11	high		300
Morgan	14	—	0	20	3	150	200	8		1,231
Noble	—	5	0	2	1	75	—	—		0
Monroe	6	15	1	0	1	—	18	1	1	390
Athens	22	40	0	20	6	100	200‡	90	0	250§
Washington	8	200	6	4	1	1,200	300	700	20	1,000
Meigs	1	16	0	2	3	100	7	—		0
Jackson	7	—	0	3	5	—	16	1		333§
Gallia	—	5	0	1	5	50	—	—		300§

* Figures compiled from data supplied by County Commissioners and/or County Health Commissioners except as noted below.
† Report of the positive tests on foxes by the Ohio Department of Health Laboratory (Ey, 1947).
‡ Approximate number. 300 claims for vaccination payments were filed with the County Commissioners between September, 1945 and June 12, 1947.
§ Bounties paid on gray fox only.

In most of the counties involved, no differentiation was made between vaccinations necessary or losses due to bites of foxes and of dogs, and as rabies in dogs was also prevalent at the same time, there is no way of even estimating the loss due to foxes. Only 16 definite

instances of people being bitten by foxes are included on the questionnaires, and only a few others have been discovered—by rumors. No effective control of rabies in dogs has been inaugurated in any of these counties to date. A quarantine is in existence, by law, in most of the counties, which may do some good. Those dog owners who are interested enough have their dogs vaccinated, but there are enough stray, unlicensed, and poorly kept dogs on the loose to keep the disease ever on the increase.

TABLE 2.—BEHAVIOR OF RABID FOXES FROM ATHENS AND MEIGS COUNTIES, OHIO, DURING FEBRUARY AND MARCH, 1947

Species	Sex	Comments
gray	F	Killed with stick as it came from den. Offered no resistance.
gray	F	Caught a chicken which farmer rescued. Went back to barn and caught another.
gray	M	Wandered into yard. Severe streptococcic infection in mouth.
gray	F	Chased cat from under house on to porch, and into house.
gray	M	Fighting with farm dog: refused to run from farmer.
gray	F	Entered barn, came out and left. Farmer followed one half mile.
gray	F	Feeding on an opossum carcass near barn.
gray	F	Seen several times at abandoned farm house. Snarled but never attacked.
gray	M	Caught in yard by dog. Killed with a broom.
gray	M	Caught in steel trap with rabbit as bait.
gray	F	Attacked man in garden. Killed with a rake.
gray	F	Trying to dig into barn. Chased farmer.
red	F	Caught a chicken and just pushed it around. Chicken lived.
red	F	In barnyard. Paid no attention to chickens or farmer.
gray	F	Attacked team but was driven off. Came at team again at next passing.
gray	M	Chased and caught a small dog. Killed with miner's pick.
gray	F	Bit four sheep, all of which developed rabies.
gray	F	Chasing a rooster around the yard.
red	M	Fighting with dog that was tied in the yard.
red	F	Attacked dog, then bit into front tire of moving truck.
gray	M	Killed 30 chickens—was caught in the act.

The cost of rabies, whether from dogs or foxes, is consistently high. Most of the counties pay for the vaccination of people exposed to rabies (700 vaccinations reported for nine counties). Some counties pay for livestock lost from rabies, but some draw the line on paying for any cases that may have resulted from fox bites. For 1946, four counties reported an estimated loss of 800 cattle and 25 horses, only a small portion of which were paid for by public funds. The records are so incomplete that to estimate the loss in the other counties involved would be only a guess, as the usual designation was "as high a loss as last year," or "greater loss than last year." It may be safely assumed that the counties in the rabies area, for which numbers were not specified, had a loss somewhere near the average for those that did report. This toll of $8,000 to $10,000, or even more, per county per year in livestock, plus $1,000, to $11,000 per county per year for rabies vaccination, plus the discomfort and the worry involved, must be charged to rabies, at least part of which is transmitted by foxes. As stated previously, in both New York and Alabama, most of the loss was charged directly to foxes. In Ohio, the charge against foxes is made, prob-

ably with good justification, but because so little has been done about dog rabies, only an occasional case can be proved, as direct observations of attacks by foxes on livestock have been very infrequent.

In Athens and Meigs Counties, the occurrence of rabies has been predominately in the gray fox although a few cases are definitely known in the red fox. The proportion in the normal population is approximately three gray foxes to one red fox, but the proportion of rabies is more nearly six grays to one red among the cases examined and fifteen to one in the cases reported, where there was any differentiation made. In New York, it is the red fox that is afflicted (Compton, 1943), while in Alabama and Georgia it is the gray fox (Johnson, 1945). In each case, the dominant species is the one most seriously involved.

Rabies in other native animals in Ohio is inadequately known. An epizootic of encephalitis of some sort, possibly rabies, nearly eliminated skunks from Southern Ohio 1940–42. Only one skunk (from Green County) was actually proved rabid by laboratory test. During the present epizootic, seven skunks have been diagnosed as rabid by the Laboratory of the Ohio Department of Health, and one (Athens County) at the Ohio University laboratory. Several groundhogs, squirrels, rabbits, and rats have been checked at the Health Laboratory, but no reports of positive findings on any of those animals have been released.

TRANSMISSION OF RABIES

There have been various speculations as to how foxes get rabies in the first place, and how the disease is maintained in the fox population. Johnson (1945) had evidence of a specific case of a dog in the beginning stage of rabies fighting with foxes at the onset of the epizootic in Georgia. Other specific instances are lacking. The Ohio Public Health Department records show a few positive cases of rabies in foxes each year for at least seven years, which indicates that the disease is enzootic in Ohio and has only recently become epizootic. The rapid spread of rabies in foxes, and skunks at times, and an absence of high correlation between numbers of cases of rabies in dogs and in the foxes nearly preclude the possibility of repeated infections of foxes by dogs. The little that is known of rabid fox behavior indicates that such animals probably do not travel far after they develop the disease, so probably the rapid spread of the disease cannot be attributed to promiscuous distribution by a few individuals. Certainly rabies must be transmitted by bite from fox to fox, fox to dog, and dog to fox; with skunks, or other carnivores sometimes entering the picture. Since reinfection of foxes by dog bite and spread within the fox population seems inadequate to explain the rapid spread over a wide area, and since rabies is known to be enzootic in at least part of the affected areas, it seems most likely that certain conditions within the population make the animals more susceptible to rabies at times, so the disease that is present becomes epizootic.

At the present time throughout the Allegheny Plateau, the fox population is at an all-time high. The present rabies outbreak has occurred in the part of Ohio where an excessive gray fox popu-

lation has been added to a near-saturation population of red fox. In Athens, Washington, and Morgan Counties, there is an average occurrence of at least three red fox and five gray fox per square mile, resulting in concentrations of twelve or more foxes per square mile in favorable habitats. Consequently, there is frequent contact between foxes so parasites and diseases of all kinds are readily transmitted from fox to fox. In addition with increased population densities, favored foods and adequate denning facilities are no longer available, resulting in greater susceptibility to parasites and diseases.

CONTROL OF RABIES

It has been demonstrated in England and Denmark that, where rabies is not enzootic in wild animals, the disease can be completely controlled by adequate quarantine of dogs (Webster, 1942). In eastern North America there now exists a condition of general infection of rabies in skunks and foxes, where no amount of killing can completely eliminate the disease, and no amount of dog rabies control can effectively reduce the disease in the wild.

It has been demonstrated also in Summit County, Ohio, that rabies can be eliminated in the dog population, where no rabies are present in foxes, by rigid enforcement of compulsory vaccination laws. In Summit County, Dr. E. R. Shaffer, County Health Commissioner reported (1947) that there were 218 cases of rabies in dogs in 1945. Compulsory vaccination was imposed throughout the county in April, 1946. During the next three months, 26,700 dogs were vaccinated and 4,015 stray and unlicensed dogs were destroyed. From November 1, 1946, to April 30, 1947, there was only one rabid dog reported for the county (Dec., 1946). Only four vaccinated dogs developed rabies, two of which were exposed before vaccination. In New York (Compton, 1943) and in Georgia and Alabama (Johnson, 1945), it has also been clearly shown that rabies in dogs can be controlled by vaccination even though the disease is epizootic in foxes in the same region. Johnson reported that fourteen foxes, later proved rabid, were killed by fox hounds, all of which had been vaccinated, and none of which developed rabies.

Control of rabies in foxes and other wild animals has been much more difficult than for dogs, the only methods at hand are: (1) let the disease run its course, resulting in decimation of the animals in question; or, (2) indiscriminate killing of susceptible wildlife to reduce the possibility of the disease being spread from animal to animal. The first is definitely nature's way and effectively eliminates the disease when the susceptible animals are so nearly all dead that there is no regular contact. This happened with foxes in Massachusetts in 1812, and in Alabama in 1890–94; in spotted skunks in Kansas in 1875; in the Ohio skunks in 1940–42, and is repeating itself in the Ohio gray fox at the present time. The second method has been used as a "cure" for rabies epizootics in the California coyote outbreak in 1915–16, in the outbreak in foxes in Alabama and Georgia (1940–47 (Johnson, 1945) and to a less extent in the outbreak in foxes in New York (Compton, 1943). Reduction in numbers as a preventative is now being practiced in New York (Zeissig, 1947)

in the form of bands of reduced populations around centers of infection, with the idea of letting the disease run its course within the area of infection. None of these methods seems to be very satisfactory, but the artificial reduction of population is not so wasteful of wildlife as is the unhampered disease, and it is less dangerous to man and domesticated animals.

In the present era of highly trained game technicians and adequate funds for management practices, it seems rather incongruous that any animal species as large, as valuable, and with as low a reproductive potential as the fox, should be allowed to exceed the carrying capacity of the land to such an extent that diseases such as rabies, distemper, and mange; external and internal parasites; and conditions of malnutrition and over exposure can destroy a large portion of the animals. An adequate system of censusing should be established in every state, then a system of control of habitats and/or controlled harvest inaugurated for each species as necessary so that extreme population levels could not be reached. By such methods, only, can overcrowding be prevented which necessarily results in disease—whether rabies, distemper, worms, or other ailments—ending with decimation of the species, followed by a long period of scarcity and close restrictions.

SUMMARY

Rabies has been reported in epizootic proportions in native carnivores of North America, in Massachusetts, Alabama, Kansas, California, Utah, New Mexico, and Arizona, principally in foxes, wolves, skunks, and coyotes. Bobcats, raccoons, and opossums have been reported to be involved in the epizootics in some numbers.

The present rabies epizootic extends from New York, west into Ohio, and south through the Allegheny Plateau into Arkansas and Louisiana. Foxes are the primary carriers in much of the area, with the disease spreading secondarily to skunks, bobcats, and possibly opossums and other forms of wild life. Except in New York, Alabama, and Georgia, the epizootic in foxes is accompanied by an epizootic in dogs, which further complicates the study and interpretation of the spread and severity of the disease in wild animals.

In Ohio, rabies in foxes is at present limited to the unglaciated plateau of the southeastern counties, and is affecting primarily the gray foxes. Several hundred cases of rabies in foxes have been reported; the actual number cannot be determined. Losses of livestock due to rabies have been high for the past two years. An undetermined portion of these losses must be attributed to foxes.

Control of rabies in wild animals must begin with positive control of rabies in dogs, by compulsory vaccination or quarantine, or both, in order to eliminate reinfection of wild animals. Beyond that, control measures must be a matter of prevention or elimination of overpopulation which leads to conditions favoring rabies and other diseases.

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THE TRAP LINE AS A MEASURE OF SMALL MAMMAL POPULATIONS

Lucille F. Stickel

U. S. Fish and Wildlife Service, Laurel, Maryland

A major need in small mammal work is simple field method that will provide accurate relative abundance figures for the comparison of the populations of different areas, or, of the same area at different times. The large area live-trap quadrat method proposed by Dice gives reliable data on the actual numbers of animals in an area and this technique is excellent for intensive local studies. It is too laborious and time consuming however for extensive studies and it is not a practical method for sampling a large number of habitats in a single season.

The large area live-trap quadrat serves as an extremely useful basis for testing simpler methods. By means of intensive trapping the population of an area can be determined and the results compared with those obtained by the simpler method on the same area immediately before or afterwards. The large area live-trapping provides population and movement data for use in interpretation and evaluation of results of the method under trial. This basis of comparison proved its usefulness in a test of the one acre snap-trap quadrat (Stickel, 1946). The present paper re-

ports a study of the live-trap line as a measure of relative abundance of small mammals.[1]

METHODS

Trapping procedure: The general plan was to compare the catch of a trap line with the catch of a quadrat enclosing and including this line. The tests were made on populations of *Peromyscus leucopus* during June, July, and August, 1946, on the Patuxent Research Refuge, Maryland.

The trapped lines were 600 feet long and were made up of traps set at 15 foot intervals. Traps were placed close together in order to provide a virtually continuous trap. The live-trap quadrat was an 8.4 acre grid with 177 traps spaced at 50 foot intervals. In this grid a row of traps followed the original trap line and there were 4 rows of additional traps on each side of the line. Traps thus extended 200 feet on each side and 200 feet beyond each end of the 600 foot line.

Two sets of tests were made in the bottomland forest and one set of tests in a young upland oak woods. In one bottomland series and in the upland series the procedure was to trap the line for 4 days, then close these traps and replace them by traps on the grid for 6 days, then close the grid traps and trap the line again for 4 days. In the second bottomland series the procedure was to trap the grid for 6 days and follow with line trapping for 4 days.

Traps and bait: Large size Sherman traps were used. These proved superior to the smaller traps of this type in that they were more easily adjusted to spring with light weight, were large enough to permit addition of an adequate amount of nesting material, and long enough that tails of the animals were not injured when the doors closed. Bait was rolled oats and peanut butter.

Marking: All animals were marked in the field and released at the sites of capture. Individuals were marked with ear tags of the fish fingerling type used successfully by Scott (1942) and Eddy and Joyce (1944). The tags, and clinchers for applying them, were obtained from the Salt Lake Stamp Company, Salt Lake City, Utah. These tags are superior to fish fingerling tags that can be obtained from other sources in that they are unusually light in weight. They do not get out of alignment or require any adjustment before application to the ear, nor do they stick in the clinchers. In hundreds of recaptures over several summer months there was no evidence of loss of tags, even of some that were improperly applied. The best place to insert the tag is at the base of the ear, below some of the cartilage, at such an angle that the tag lies flat against the head.

BOTTOMLANDS TRIAL I

In the first trapping series in the bottomlands, June 8–11, twenty mice (12 males and eight females) were caught on the 600 foot line. This same line, re-trapped June 25–28, again took twenty mice (13 males, seven females). The 8.4 acre plot surrounding and enclosing the line was trapped between these two periods, June 12–17. In this area trapping 103 mice were taken, 51 males and 52 females.

[1] Acknowledgments are made to Harold Angle and Charles Schaffer for assistance in the field work and to Mrs. Katheryne Tabb for preparation of the maps.

TABLE 1.—KNOWN RANGE OF MICE AT SUCCESSIVE CAPTURES. FIRST BOTTOMLANDS TRIAL

Repeat Capture Number	Males			Females		
	Number of Mice	Range of Movement (feet)	Average Movement	Number of Mice	Range of Movement (feet)	Average Movement
2	41	0–200	66.8	39	0–150	49.1
3	30	0–180	100.2	26	0–205	78.7
4	20	0–220	114.0	14	50–205	100.4
5	12	50–220	136.3	7	100–205	125.0
6	5	70–160	133.0	2	100	100.0

Most of the mice that were collected by the line of traps were also taken in the area trapping. Of the 12 males taken in the first line-trapping eight were also taken in the area trapping. Likewise seven of eight females were re-taken during the area trapping. Mice that were taken in the traps on the line were usually taken very near these same places in the area trapping. All of the males were taken on the grid at positions no more than one trap (50 feet) distant from the line. One female was caught two traps (100 feet) from the line. All other females were taken on the line or within 50 feet of it.

The results of the line-trapping following the area trapping were very similar to the results of the first line trapping. In this second trial all 20 animals that were taken on the line had also been taken in the area trapping. Their locations of capture were similar in both, for 14 of the 20 were caught on the line or within one trap of it and six others (three males and three females) were caught within 100 feet of the line.

The results of the grid trapping can be used to estimate the size of the population (Stickel 1946) by the method described briefly below: A marginal strip 75 feet wide, including the two outermost rows of traps is considered a buffer zone. The population is then calculated for the 4.57 acre central plot. All animals taken only in the central area are attributed to it. In addition, one-half of the animals taken in both the central plot and the buffer strip are attributed to the central plot. The population of the central plot in this example is thus calculated to consist of 40 animals (21 males and 19 females). The number per acre is calculated to be eight or nine mice, with males and females present in approximately equal numbers (males 4.6, females 4.2). The population consisted of adult animals, subadults, large juveniles, medium sized juveniles, and toward the end of the period a few very small juveniles. Because of practical difficulties in separation of the groups, the figures above include animals of all ages.

The results of the area trapping likewise give information concerning the range of the mice. The maximum travel range recorded for most mice is however probably less than the actual range. There is an upward trend in average maximum range at succeeding captures, although the differences are not significant statistically. These data are summarized in Table 1.

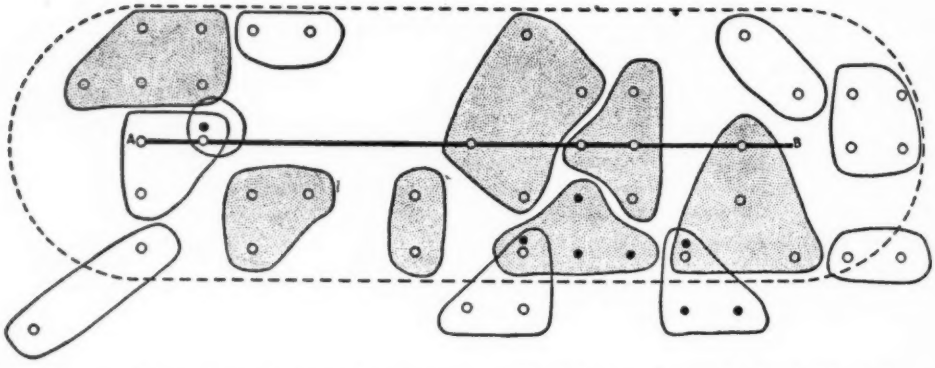

FIG. 1.—Comparison of line and area trapping of adult female wood mice in the bottomlands. The dotted line encloses a 4.57 acre area. All mice collected within or both within and outside this area are shown. (Traps were at 50 foot intervals over an 8.4 acre area.) The sites of capture are spotted in and surrounded by solid lines. Trapping of the 600 foot line a–b, with traps at 15 foot intervals, resulted in the capture of the mice shown by shading, plus one other mouse not taken in the area trapping.

From the general trend and from the maximum distances the actual average range is estimated to be at least 150 feet for males and at least 100 feet for females.

BOTTOMLANDS TRIAL II

The second bottomlands trial was made in mid-August on the same plot used in the June test. In this second trial no line trapping was done until the area trapping was completed. The 8.4 acre plot was trapped for six days, August 9 to 14, and 112 mice were captured. These were distributed as follows: 50 adult males, 42 adult females, 13 juvenile males, seven juvenile females. The line was trapped August 15 to 18, immediately after the area trapping. The line of traps took twenty mice: sixteen (8 males, 8 females) were adult animals, four (two males, two females) were juveniles.

Most of these mice, collected on the line, were also taken in the area trapping. These include all ten males and eight of the ten females. The sites of capture were similar in both trapping periods. During the area trapping all of the females (except the two new ones)

TABLE 2.—KNOWN RANGE OF MICE AT SUCCESSIVE CAPTURES. SECOND BOTTOMLANDS TRIAL

Repeat Capture Number	Males			Females		
	Number of Mice	Range of Movement (feet)	Average Movement	Number of Mice	Range of Movement (feet)	Average Movement
2	38	0–200	60.9	34	0–315	66.0
3	31	50–180	99.0	27	0–150	69.4
4	23	50–200	113.3	15	50–150	90.7
5	11	50–335	127.5	7	70–115	100.0
6	4	50–145	87.5	2	115	115.0

and all but one of the males had been recorded on the line or within one trap (50 feet) of the line. One male was taken no closer to the line than 150 feet. Data for adult females are shown diagrammatically in Figure 1 as an example of the relationships between the line and area trapping results.

The population was estimated from the results of the area trapping by the method described for the first bottomlands trial. The population was calculated to be about eight mice per acre (six or seven adults and one or two juveniles per acre). The figures for the groups are: adult males, 3.28; adult females, 3.06; juvenile males, .98; juvenile females, .66.

The range sizes found in the area trapping are probably less than the actual ranges. The average maximum movement of adults as shown by succeeding captures appears in Table 2. The actual average range appears to be very similar to that of the first bottomlands trial. It is estimated to be at least 150 feet for males and at least 100 feet for females, on the basis of the general trends and maximum range values of the table.

UPLANDS TRIAL

The uplands trial was made during the interval between the two bottomlands trapping series. The general plan was the same as in the first bottomlands tests. In the first line-trapping, June 25 to 28, five adult mice (three males and two females) and three juveniles (two males and one female) were caught. When the line was trapped again July 15 to 18, following the area trapping, four adult mice (three males and one female) and one juvenile (female) were captured. The 8.4 acre plot surrounding the line was trapped between these two periods. Twenty-four mice were taken in the six days,

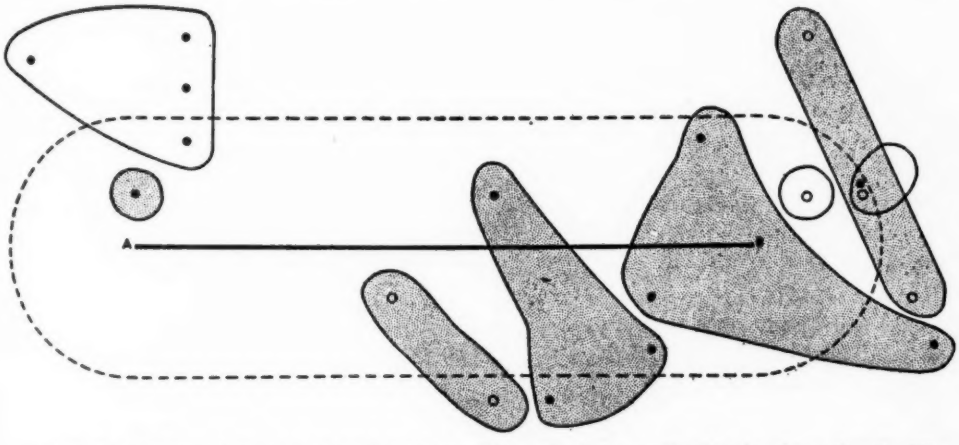

FIG. 2.—Comparison of line and area trapping of adult wood mice in the uplands. The dotted line encloses a 4.57 acre area. All mice collected within or both within and outside this area are shown. (Traps were at 50 foot intervals over an 8.4 acre area.) The sites of capture are spotted in and surrounded by solid lines. Solid dots represent males; open dots represent females. Trapping of the 600 foot line A–B, with traps at 15 foot intervals resulted in the capture of the mice shown by shading.

June 29 to July 4. There were ten adult males, 11 adult females, two juvenile males and one juvenile female.

All mice collected on the line were also taken in the area trapping. Of the eight mice taken in the first line trapping, four of the five males had ranges crossing the line or were taken within one trap (50 feet) of the line. The fifth male, a juvenile, was caught no closer to the line than 150 feet. Two of the three females were taken within 50 feet of the line; one was taken 115 feet distant. Sites of capture of adult mice of this group are shown on the map in Figure 2 as an example of the relationship between line and grid trapping results. Of the five mice taken in the second line trapping, one male was taken within 50 feet of the line, one 150 feet distant, and one 200 feet distant. One female was taken on the line, the other within 50 feet.

The population size can be estimated by the method used in the bottomlands studies, but the estimate will be less reliable. The reason for this is that it is unlikely that the range of any animal was actually confined to the central plot. Therefore, estimation by the procedure described for the other area will give an estimate that is somewhat larger than the true population size. The per-acre estimate would be about one adult mouse and fewer than one juvenile per acre (.77 adult male, .44 adult female, .22 juvenile male, .11 juvenile female). These figures can be considered maximal. An estimate of one mouse per acre would probably not be too low.

The information on range sizes found in the area trapping of the uplands plot is useful for comparison with the smaller bottomlands ranges, although the actual ranges of individual adult mice are almost certainly larger than the distances recorded in the area trapping These distances at successive captures are shown in Table 3. The increase in average movement with succeeding captures suggests that the actual ranges are at least 275 feet for males and 250 feet for females.

TABLE 3.—KNOWN RANGE OF MICE AT SUCCESSIVE CAPTURES. UPLANDS TRIAL

Repeat Capture Number	Males			Females		
	Number of Mice	Range of Movement (feet)	Average Movement	Number of Mice	Range of Movement (feet)	Average Movement
2	8	0–275	75.0	7	0–140	52.9
3	6	70–275	143.3	6	45–225	114.2
4	5	105–300	189.0	2	60–265	162.5
5	1	160	160.0	1	140	140.0

DISCUSSION

The size of the mouse populations of bottomlands and uplands can be compared on the basis of the area trapping per acre estimates. The validity of the lines of traps as measures of relative abundance of mice in bottomlands and uplands can then be checked by direct contrast. On the basis of area-trapping

TABLE 4.—COMPARISONS OF LINE AND AREA TRAPPING

	Taken on Line Preceding Area Trapping			Taken on Line After Area Trapping			Area Trapping Estimate of per Acre Population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Bottomlands I (adults & juveniles combined)	12	8	20	13	7	20	4 or 5	4 or 5	8 or 9
Bottomlands II	—	—	—	8 ad 2 j.	8 ad 2 j.	16 ad 4 j.	4 or 5	3 or 4	8
Uplands	3 ad 2 j.	3 ad 1 j.	6 ad 3 j.	3 ad	2 ad 1 j.	5 ad 1 j.	1 or <1	<1	about 1

per-acre estimates it was found that mice were five to eight times as numerous in bottomlands as in uplands plots. By contrast, the catch of the 600 foot lines through the same plots showed only 2.5 to four times as many mice in the bottomlands as in the uplands (see Table 4).

It is apparent that the habitat comparisons based on line trapping results are distorted, and indicate a proportionally higher uplands population than actually existed. The reason for the distortion is that the animals in the uplands ranged more widely than the animals in the bottomlands and so increased the effective trapping area of the line.

The range differences in the two habitats are apparent on the sample maps (Figures 1 and 2). Travel distances recorded after equal numbers of captures in the two habitats give an approximation of the differences. Comparable known ranges after 3 and 4 captures are shown in Table 5 (see also Tables 1–3).

These variations in range size and population size were in habitats less than one mile apart.

Similar variations in cruising ranges have been found in studies by other workers. In some the differences seemed to be correlated with food supply. Certain of these findings are briefly summarized below.

Prairie deer mice and meadow mice with winter quarters in shocked corn moved only a fraction of the distances traveled by those living in adjoining

TABLE 5.—KNOWN RANGE OF MICE IN BOTTOMLANDS AND UPLANDS AFTER 3 AND 4 CAPTURES

	Adult Males (3 Captures)			Adult Females (3 Captures)		
	Mean	Standard Deviation	σ_M	Mean	Standard Deviation	σ_M
Bottomlands Trial II	99.0	39.5	7.1	69.5	29.2	5.6
Uplands	143.3	69.7	29.0	114.2	73.4	30.6
	Adult Males (4 Captures)					
Bottomlands Trial II	113.3	40.1	8.4			
Uplands	189.0	72.1	32.8			

fields of wheat stubble (Linduska 1942).

Male meadow mice were found to have smaller ranges in moist than in dry grassland (Blair 1940).

The home ranges of two species of New Mexico mesquite association mammals, *Peromyscus maniculatus* and *Peromyscus leucopus* were found to be larger than those of other races of the same species studied in the bluegrass, beech-maple, and oak-hickory associations in Michigan (Blair 1943).

The probability of correlation between range size and environmental factors has been discussed by several authors. Kalabukhov (1935) bases his theory of population dynamics in part on this relationship, stating that the more food there is in a given territory, the smaller is the radius of movement of rodents, and the less the possibility of their death from predators (from Elton 1942).

Dice (1938, p. 129) in a discussion of census methods specifically warns that, "Due consideration must be given to possible variations in the sizes of the cruising ranges at the various seasons and in the various types of habitats occupied." Burt (1940) states that, "The size of the area occupied by any animal is limited by that animal's ability to travel and its necessity for food and protection."

In discussing home range sizes Dice (1941) stated " . . . the size of home range often varies with the season and perhaps also with the available food supply and with the density of population." Burt (1943) says, "The size of the home range may vary with sex, possibly age, and season. Population density also may influence the size of the home range and cause it to coincide more closely with the size of the territory."

Because variations in range may be associated with variations in habitat and food supply, single lines of traps, however long or numerous, can not be considered reliable means of measuring relative abundance of mammals. This applies equally to comparisons of relative numbers of *different* species of small mammals in the same habitat and to comparisons of numbers of animals of the same species in different habitats. It will also apply to comparisons of numbers of animals of a given species in one habitat at different seasons or in different years. The same conclusions will apply to uncorrected data from any small area sampling method.

How population size is related to size of individual range and how the two are correlated with habitat factors of food and cover are unsolved problems. In the present study the mice in the smaller uplands population had the larger ranges, and the mice in the larger population of the bottomlands had the smaller ranges. Therefore the comparisons by the line trapping made the population of the two areas appear to be closer to each other than they actually were. Nevertheless the difference in population size in the two habitats was so great that a difference was apparent even by the trap line method. It might be casually assumed that if differences between habitats were revealed by this method of trapping the differences would be valid, because the error in the method would minimize rather than exaggerate the differences.

However, it is by no means certain

that range sizes are always larger when populations are smaller or that range sizes increase when population size decreases. Little or no study has been made of these relationships, and it is possible that line-trap comparisons under some conditions might exaggerate rather than minimize differences. For example, such factors as population decimation by disease or a rapid depletion of food supply might produce a very different relationship between range and population size than that found in the present study.

SUMMARY

The value of a line of traps as a measure of relative abundance of small mammals was studied by field trials on *Peromyscus leucopus* populations. Comparisons were made between the numbers of mice captured by a line of live traps and the numbers captured in intensive live trapping of a larger area surrounding the line. Trials were made in bottomland woods where mice were numerous and in upland woods where mice were less common.

It was found that wood mice living in upland woods had significantly larger cruising ranges than those living in bottomland woods. Consequently, a line of traps in the bottomlands captured mice from a smaller surrounding territory than in the uplands. Therefore, comparisons of relative size of the mouse population in these two areas on the basis of line-trapping showed an erroneously large number for the upland woods.

As a result of these trials and the studies of other workers, it is concluded that lines of traps are not fully reliable means of measuring relative abundance of small mammals.

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THE PLACENTAL SCAR AS A MEASURE OF FERTILITY IN RATS[1]

David E. Davis and John T. Emlen, Jr.
The Johns Hopkins University, Baltimore, Maryland

Studies of reproduction and population dynamics of wild mammals have been handicapped by the absence of a technique for determining reproductive histories of individual females. For captive animals it is a simple matter to count the number of young produced by a given female, but the unmeasured effects of confinement make it impossible to apply these figures to animals living in the wild state.

Various workers have suggested that counts of the pigment spots left on the uterus at the sites of implantation might serve as indicators of reproductive history. These spots, commonly referred to as "placental scars," "uterine scars" or "placental sites" have been noted and are located on the mesometrial side of the uterus at the base of the mesentery. Deno (1937, 1941) described the details of the formation and involution of these structures in the laboratory mouse and Masson and Selye (1942) described the movement of the placental scar to the mesometrial site in the albino rat.

No critical work has been done, however, to test the reliability of placental scar counts as indicators of the number of young produced. In some species the presence of placental scars has been noted and a few counts have been made. Sooter (1946) found in muskrats from 0–26 scars with an average of 14.1 scars per female. Stuewer (1943) concluded that a female raccoon had had 4 young because the uteri had 4 scars.

The object of this investigation was to compare the number of young produced by each female rat with the number of placental scars found in each reproductive tract at autopsy.

Methods

Virgin female tame hooded and a few brown rats (*Rattus norvegicus*) were repeatedly bred and the number of young counted at each parturition. After producing several litters the females were killed, the scars counted, and the entire reproductive tract was preserved either in Bouin's or in 4 per cent formaldehyde. It was found that the yellow color of the Bouin's completely concealed the scars but that after washing in water the scars were more clearly visible than the scars in uteri preserved in formaldehyde. There were no differences in the counts made before and after preservation. When a female ate part or all of a litter she was killed, the number of young left and a plus sign were added to previous production record.

To check the possibility that scars could appear without placental implantation a series of 16 virgin rats were isolated from males for six months and examined.

To check the persistence of the scars over long periods of time in another

[1] Contribution from the Rodent Ecology Project, Johns Hopkins School of Hygiene and Public Health, Baltimore, Maryland.

series parous rats were isolated for periods of six and nine months.

RESULTS

A comparison of the number of placental scars and the number of young produced by hooded and by captive brown rats is presented in Table 1. There is a general relationship, but it is obvious that the 2 values cannot be equated. Scars were notably fewer than young in 9 out of the 21 specimens, comprising as little as 1/5 in one case (no. 29). Scars, on the other hand, definitely outnumbered young in 4 specimens, by as much as $3\frac{1}{2}$ times in rat no. 19.

An excess of young over scars might be attributed to a regression and disappearance of scars with time. However, the 12 parous rats held for periods of from 6–9 months to test regression all retained clearly visible scars at autopsy. One brown rat had scars after 3.5 months in isolation. Another in which scar count was made by laparotomy before isolation retained all the scars during 13.5 months of isolation. The small number of scars in the rats is therefore more likely due to a coalescence of scars or a superimposition of implantations rather than to disappearance with time.

However Perry (1945) found about 40 rats over 200 gms. in weight which were parous according to results of an examination of serial sections of the ovaries and yet lacked placental scars. Perry's results would indicate that the scars were absent in some parous rats,

TABLE 1.—COMPARISON OF NUMBERS OF YOUNG AND SCARS IN RATS

Rat No.	Young Born	Scars	Ratio young:scars	Months*	Condition of Uterus
			HOODED RATS		
12	93	X	—	11	Turgid
4	8	X	—	4	Pregnant
13	7	9	.78	1	Small
34	7	8	.87	.5	Very large and vascular
14	7+	9	—	1.5	Small
19	8	29	.28	4	Small
8	9+	13	—	7	Small
11	12+	20	—	2.5	Small
1	13+	8	—	6	Small
9	19+	25	—	3	Small
47	25	23	1.09	4.5	Large
39	30	18	1.67	4.5	Small
28	30+	39	—	6	Turgid
30	33	30	1.10	4	Very large
36	36	25	1.44	5	Small
16	36	8?	—	9	Turgid
29	39+	8	—	11	Slightly turgid
6	48	14	3.42	11	Small
38	48	38	1.26	6	Slightly turgid
			BROWN RATS		
4	6	6	1.00	.5	Small
2	17+	15	—	2	Small
3	16	32	.50	1.5	Small
1	42	25	1.68	9	Small

* This column gives the time between first pregnancy and autopsy.
X = Scars present but impossible to count accurately.

which is at variance from the work here reported.

The instances of an excess of scars over young produced could be readily accounted for if, as is suspected, resorbed fetuses leave scars. In the 16 virgin females held till eight months of age no placental scars were found although one rat had a darkened area that scars accumulate and persist over most of the reproductive span of an individual. This number should therefore be valuable as a rough indication of reproductive history in the rat.

In Table 2 it will be noted that some fairly large female rats (240–259 mm.) lacked placental scars and presumably had not become pregnant.

TABLE 2.—PLACENTAL SCARS OF WILD BROWN RATS

Length of Head and Body	Placental Scars of Rats with Perforate Vagina								
	0	1–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79
170–179 mm.	26								
180–189 mm.	34	1							
190–199 mm.	42	1							
200–209 mm.	30	9	3						
210–219 mm.	43	5	6		1				
220–229 mm.	22	15	7	6	2				1
230–239 mm.	18	10	17	10	11	1			
240–249 mm.	9	5	7	12	10	3	4	2	1
250–259 mm.	2	3	3	7	9	7	4	3	1
260–269 mm.		1	1	1	2	5	2	1	
270–279 mm.						1	2		
280–289 mm.						1			
Totals	226	50	44	36	35	18	12	6	3

superficially resembling a placental scar at some distance from the mesometrial border of the uterus.

SCAR COUNTS OF WILD RATS

Counts of the number of placental scars were made on 430 wild female brown rats caught in Baltimore. Although the laboratory tests described above show that scar counts cannot be used as a reliable indicator of reproductive history in individual rats, it is interesting to compare scar counts with body length. The data presented in Table 2 show a positive correlation (0.60) between the number of scars and the length of the animal, suggesting

INCEPTION AND DURATION OF REPRODUCTIVE ACTIVITY

Since presence of scars in rats apparently indicates that the individual has had young, the placental scars may be used to determine the size at which the rat first reproduces. Thus if the animals are grouped by size and classed as parous (individuals with scars or visible embryos) or non-parous (individuals without scars or visible embryos) a measure of the size at first pregnancy is obtained. Only a slight error is introduced if the primiparous individuals with non-visible embryos are classed as "not-pregnant." Table 3 shows the data for a sample of female roof rats

(*Rattus rattus*) and of female brown rats from San Antonio, Texas and for female brown rats from Baltimore. The body length at which 50 per cent of the rats had scars or were visibly pregnant was calculated by plotting the percentages on arithmetic probability paper and drawing a line by inspection. The body length was read at the junction of this line and the 50 per cent line. The 50 per cent point for roof rats in San Antonio is 163 mm., for brown rats in San Antonio is 178 mm., and for brown rats in Baltimore is 224 mm.

Since size of rats differs from place to place it is necessary to obtain a ratio when comparing two groups. Roof rats are smaller than brown rats, and brown rats in San Antonio are smaller than brown rats in Baltimore. If a ratio of the size at which 50 per cent of the rats have scars to the mean size of the parous rats is calculated, then the populations can be compared. For roof rats in San Antonio the ratio is .915; for brown rats in San Antonio the ratio is .860 and for brown rats in Baltimore the ratio is .930. Since the difference between these ratios for brown rats is statistically significant it may be concluded that the brown rats reproduced at a smaller size in San Antonio than in Baltimore. This

TABLE 3.—PER CENT OF RATS PAROUS IN RELATION TO BODY LENGTH

Head and Body Length Class in mm.	San Antonio				Baltimore	
	Roof Rat		Brown Rat		Brown Rat	
	Females* Examined	% Parous	Females* Examined	% Parous	Females* Examined	% Parous
80–89	2	*0*				
90–99	14	*0*	5	*0*	0	—
100–109	17	*0*	4	*0*	0	—
110–119	37	*0*	18	*0*	0	—
120–129	36	*0*	15	*0*	2	*0*
130–139	49	*0*	21	*0*	6	*0*
140–149	62	*6.5*	28	*0*	6	*0*
150–159	82	*22.2*	33	*9.1*	17	*0*
160–169	74	*60.8*	45	*6.7*	23	*0*
170–179	100	*81.0*	42	*45.3*	26	*0*
180–189	53	*96.2*	79	*68.4*	35	*2.9*
190–199	12	*100*	65	*89.2*	43	*2.3*
200–209	3	*100*	65	*100*	42	*29.9*
210–219	2	*100*	52	*100*	55	*21.8*
220–229	1	*100*	19	*100*	53	*58.8*
230–239			10	*100*	67	*73.2*
240–249			5	*100*	53	*83.0*
250–259			2	*100*	39	*94.8*
260–269					13	*100*
270–279					3	*100*
280–289					1	*100*
Mean length of Parous Females	172.8 ± 14.2		201.9 ± 18.9		235.4 ± 13.3	
50% point	163 mm.		178 mm.		224 mm.	

* Only females with perforate vagina included.

indicates that a larger proportion of the rats in San Antonio are of breeding age than in Baltimore. This result might be due to the fact that in San Antonio the rats were obtained largely by repeated trappings in the same places whereas in Baltimore the rats were captured in intensive campaigns in a short period of time.

Leslie *et al.* (1946) calculated the weight at which 50 per cent of the rats had ovulated. The placental scar method gives the size at which rats first produce young. The former measurement has particular value for physiological studies of comparative development; the latter has greatest application in problems of population dynamics. Leslie found that one of his samples differed from the other three but he does not discuss the biological meanings nor compare with the size of the rats. Since he used weights his figures cannot be compared with San Antonio or Baltimore figures.

SUMMARY

The reliability of placental scars as indicators of reproductive history was tested directly on a series of laboratory rats and wild brown rats. Although scars did not occur in virgin rats and were persistent in all parous rats, their number was found to be no more than a very crude indicator of the number of young produced. The discrepancy between the two counts varied several hundred per cent in both directions.

Counts of placental scars in wild-trapped rats showed a general relationship with body size, the largest numbers (70 to 80) being found in large rats. This suggests that scars accumulate and persist during the reproductive span of wild rats and may serve as a crude record of reproductive history.

A separation of females into parous or non-parous on the basis of the presence or absence of scars and/or embryos made it possible to show relationships between body size and the occurrence of first pregnancy. Brown rats from San Antonio, Texas, started breeding at a relatively smaller size than rats of the same species from Baltimore, Maryland.

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MORTALITY AND MOVEMENT OF BROWN RATS (*RATTUS NORVEGICUS*) IN ARTIFICIALLY SUPER-SATURATED POPULATIONS[1]

John B. Calhoun

The Johns Hopkins University, Baltimore, Maryland

Introduction

Management of rats consists of reducing the availability of food and harborage and the utilization of poisons to obtain low population levels. When sources of food and harborage are eliminated the rats must emigrate or remain and die. The present report assembles some of the data concerning the artificial production of supersaturated populations. Such populations exist wherever more rats occur in an area than that area can support. By introducing rats into blocks which have previously maintained a stable population of rats at the apparent level of the carrying capacity of the block we have simulated some of the conditions which should arise due to immigration or to a sudden reduction of harborage or food supply. The object was to obtain information relating to: (1) the reaction of native rats to the introduced aliens; (2) the fate of the introduced rats.

Experimental Procedure and Results

The habitat of the brown rat (*Rattus norvigecus*) studied here consisted of the back yards of row-house residential areas (Emlen, *et al.*, 1948, in press). As seen in Figure 1, the blocks are relatively isolated due to the type of housing. Movement in and out of the block by rats may only occur at the alleys at either end of the block. Three experiments bear on the present problem.

Experiment I

Three blocks were selected for this experiment. The North block and the Central block contained stable populations with many adults but few reproducing females. The South block contained an expanding population with many young individuals. Until two months prior to the study many rats had been removed from this latter block by poisoning and trapping. The difference in the percentage of rats over 270 grams in the populations reflects their condition regarding the intensity of reproduction (see Table 1).

Periodic censuses (Table 1) of these blocks were made by the sign census technique (Emlen, *loc. cit.*; Richter and Emlen, 1945). Seventy-five rats caught in box traps in the Central block were toe-clipped for later identification and released at the site of capture. One-hundred-twelve aliens were released in the central court (Figure 1) of the Central block after they were marked. They moved in all directions from the point of release and so apparently were initially well distributed over the block.

Initial invasion: The alien rats were released without the knowledge of the people in the block. Nevertheless, the people in the block noticed the change.

[1] Contribution from the Rodent Ecology Project, Johns Hopkins School of Hygiene and Public Health, Baltimore, Maryland.

TABLE 1.—POPULATION DATA OBTAINED FROM TRAPPING RECORDS IN EXPERIMENT I

	South Block	Central Block	North Block
September 23 Population	131	168	101
Resident Rats Marked October 1–4	0	75	0
Marked Alien Rats Released October 10–28	0	112	0
October 31 Population	219	261	101
Retrapping data (Nov. 5 to Jan. 17)			
1. Unmarked rats	79	46 (85)*	33
2. Marked residents	0	37	0
3. Marked aliens	0	9	1
4. Percentage over 270 grams	*38.1*	*74.4*	*73.4*

* A total of 85 rats were trapped, however only 46 were of such a weight as to indicate that they were old enough to be out of the burrows on October 1.

They began telling the writer how much worse the rats were becoming. Rats began to invade yards lacking suitable harborage or food supply. Feces and other signs were found in all yards, even those where no sign of rats had previously been noted.

Mortality increase: Between October 10 and 28, the period of release of the alien rats, 31 casualties were recorded. No such period of increased mortality was noted at any other time during the three months when frequent visits were made to this area. One marked and three unmarked residents were found dead in the alleys. Three aliens were similarly found. One alien and two unmarked rats were found run over by cars in the street where the alleys enter. Ten were reported to have been killed by residents and 11 by their dogs. The evidence was that there was no duplication in these mortality data.

Relative abundance in block: Eighty-three of the 168 resident rats (49.4 per cent) were caught during the second trapping period in the Central block. If the alien rats entered the traps as readily as the resident rats then the nine aliens caught should represent approximately 49.4 per cent of the aliens still surviving in the block. If this is so, at most only 18 (16 per cent) of the original 112 introduced into the Central block still survived there. These figures indicate that from three to five times as many native as alien rats remained in the block.

Movements of alien rats: The positions at which alien rats were found dead or recaptured indicates that they became fairly well distributed through the Central block. There must have been at past a slight tendency during this experiment for aliens to emigrate since one was found dead in the street and another was trapped in the North block. This latter rat was a young male, and it is to be noted that it was in the most accessible yard after it had left the

Central block. Despite the fact that 112 rats were trapped in the North and South blocks, no other marked rats released in the Central block were captured. Blocks farther away were not trapped. Therefore, no data were

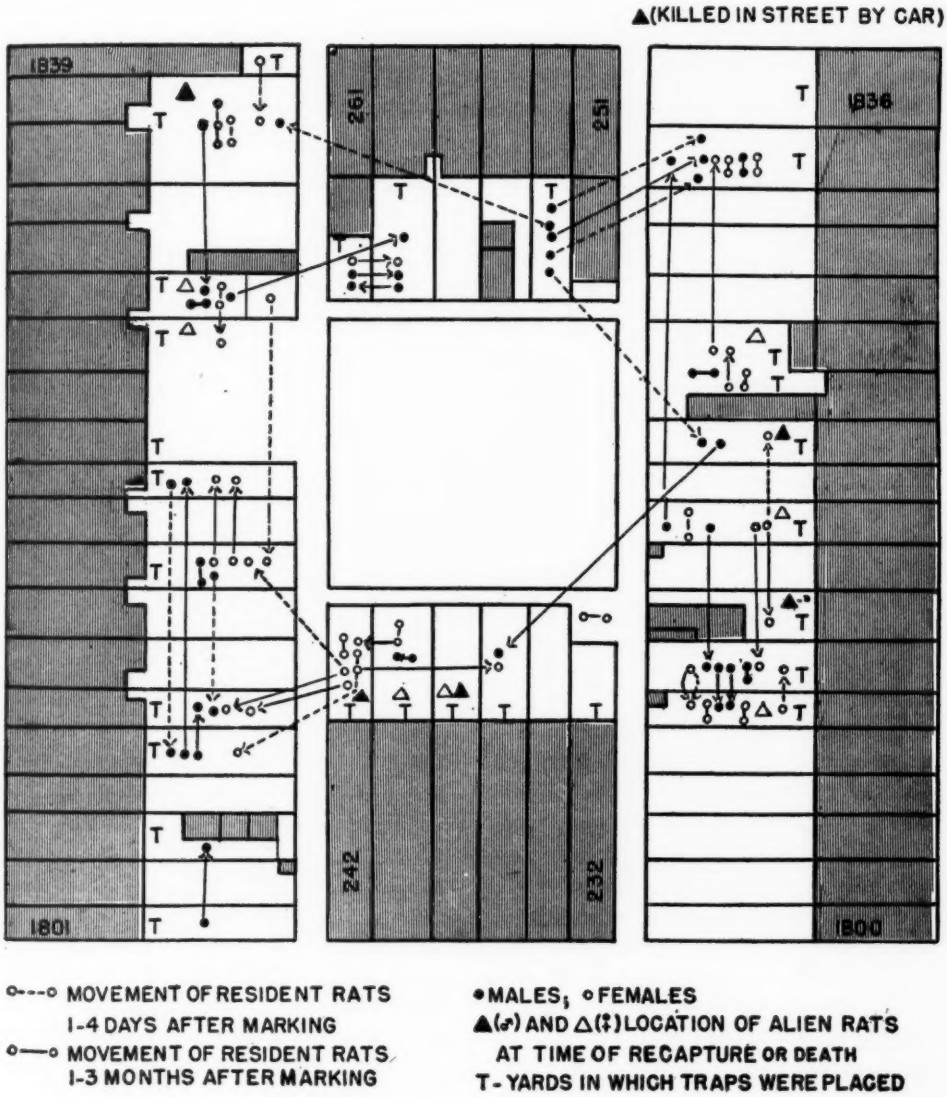

FIG. 1.—Central block. Alien rats were released in the center of the central court. Yards average 18 feet in diameter.

gathered relating to the occurrence of more extensive movements.

Movement of resident rats: Marked resident rats were retrapped both during the initial period of marking and during the later period of trapping. The points of recapture in relation to the original site of capture are shown in Figure 1. These indicate that there was a tendency for rats to be caught nearer their original site of capture after a lapse of one to three months.

EXPERIMENT II

In conjunction with his studies on home range of rats Dr. John T. Emlen gathered data bearing on the present problem. Eighteen resident rats were marked and released near the center of a long city block (800 feet) in a limited area about 60×135 feet. This block apparently contained a stable population. Nineteen aliens, captured 25 blocks away, were also introduced into this tract. During the next month the entire block was trapped with a total catch of 213 rats. No marked rat was later captured farther than 110 feet from the center of the original site of release. Of the 10 resident rats recaptured only one was caught outside the original area of release. There was an area nearly 300 feet long at either end of the block where no marked rats were caught. Although the numbers of marked individuals are small, it is to be noted that more than twice as many residents as aliens were retrapped. Fifty-three additional rats were taken during the second trapping period from the block to the north and the block to the east but no marked rats were caught.

EXPERIMENT III

A somewhat similar experiment to experiment I was earlier conducted by Drs. David E. Davis and John T. Emlen. A series of three blocks designated A, B, and C were used. Forty-nine rats from blocks A and C were released in the central B block. Within the first six days after release six had returned to their home block, one went to the opposite block, while seven remained in the B block. A second period of trapping from 34 to 84 days after release showed that three rats had stayed in their home block, three remained in the B block, and one was still in the opposite block. It seems, therefore, that when the rats do not have far to return, as many return home within a few days, as remain where they were introduced. Those which remained in the B block averaged 288 grams whereas those which returned home averaged 343 grams. Perhaps the homing urge was greater in the older rats.

DISCUSSION

When alien rats are introduced into an already stabilized population, the dynamics of the population become so altered that a high incidence of mortality occurs. Both aliens and native rats are included in this increase in mortality. We were able to obtain no exact information on the reason for this increase in mortality. However, the following may be inferred. The pressure of aliens invading their burrows forced some of the native rats to emigrate. This is evinced by the fact that two native rats were found in the street run over by cars. Such deaths at other times are much less frequent. Perhaps both alien and resident rats were involved in the invasion of yards where rats previously did not occur and in which they were unable to establish themselves

during the month prior to retrapping the rats. This abnormal movement made the rats more subject to predation by cats, dogs, and humans.

Despite the fact that a large number of young of the resident rats were weaned during the time of release of the alien rats, there were only 261 rats in the block three days after this time whereas there should have been over 300 rats with these additions. Later trapping showed that the introduced aliens had disappeared from the block at least three times as rapidly as the adult resident population existing at the time of the introduction. Either the aliens experienced a higher mortality rate or they emigrated from the block of their liberation. Creel's data (1915) seem to show that when large numbers of rats are simultaneously introduced into a strange environment, many of them make extensive journeys. This results in a wide dissemination of the introduced rats. Our studies were not designed to check on this point, since only the two blocks most accessible to the rats which might leave the block of introduction were trapped. The fact that only one alien rat was trapped among the 113 rats taken from these 2 blocks indicates that if they did emigrate they did not stop in nearby blocks in appreciable numbers.

Also the fact that no rats from the Central block were taken from the two adjoining blocks indicates that the pressure of the introduced rats did not force them into any extensive emigrations. In fact the retrapping data showed that the native rats were still within their original home ranges (Figure 1).

It was found in the third experiment cited that when rats are taken from one block and introduced into an adjoining one as many remain where released as return to their home block. A similar situation may well have existed among the alien rats in the first experiment cited. Then the proportionate survival of alien rats was 18 out of 112 (16 per cent) for the aliens as opposed to 37 out of 75 (49 per cent) for the resident rats.

From these preliminary studies we may conclude that sanitation procedures which involve the limitation of availability of food or harborage for rats are unlikely to increase more than temporarily the numbers of rats in adjoining areas. It is therefore frequently unnecessary to poison or trap rats prior to alterations which make the environment untenable for rats, unless the environmental control is to be instituted on populations of rats known to harbor human diseases. Failure to precede environmental control by killing techniques at such times may result in a wide and rapid dissemination of the disease carrying rats.

SUMMARY

1. Three experiments are described in which alien brown rats (*Rattus norvegicus*) were introduced into stable populations which were already at or near the limit in numbers imposed by the carrying capacity of the area.

2. No marked resident rats left their native block.

3. In each of the experiments part of the alien rats became incorporated into the existing population.

4. When the home of the alien rats is an adjoining block as many return home as remain in the block where they were introduced.

5. When the home of the alien rats is in an area several to many blocks away

extensive emigration may occur.

6. A high mortality among both resident and alien rats occurred shortly after the release of the aliens. By the end of three months the aliens were presumed to have experienced three times the mortality as the residents.

7. Despite the temporary increase in the size of the population beyond the level which normally occurred in the block the resident rats remained within their previously existing home ranges.

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LEVEL DITCHING TO IMPROVE MUSKRATS MARSHES[1]

Wallace L. Anderson

U. S. Soil Conservation Service, Milwaukee, Wisconsin

The idea of wildlife production as a land use is relatively new in agriculture. Many marshes do not make permanently productive cropland or pasture if drained but can be used profitably as wildlife land, principally for muskrat production. Because there is practically no published information on the dollars-and-cents value of level ditching as a marsh management technique, an economic analysis of this practice was undertaken. The results may help farmers and others to plan the most appropriate use for wet land.

METHOD

The analysis was made by examining three marshes where level ditches had been installed, and by interviewing the landowners who were asked a standard set of questions prepared in advance. The data obtained from the interviews were later supplemented by correspondence with the owner who kept the most detailed records of his operations, and with the Wisconsin Conservation Department.

DESCRIPTION OF THE MARSHES

All of the marshes studied are located in the morainic area of Wisconsin, within a 25-mile radius of Oshkosh. The soils of these marshes are peat and muck overlying clay subsoil. All are

[1] The writer is indebted to the three marsh owners who contributed their time and the records vital to the analysis; to Mr. Harry Klemme, president of the Wisconsin Licensed Muskrat and Beaver Farmers Association, who contributed data from his records on land valuations, labor and equipment requirements, fur prices and tax rates; to the Wisconsin Conservation Department for records of muskrat catches, land valuations and general information; to Edward H. Graham, L. V. Compton, H. O. Anderson, U. C. Nelson, and Henry Hopp of the U. S. Soil Conservation Service; and to Warren W. Chase and Mrs. Elizabeth Beard, University of Michigan for criticisms and suggestions on the manuscript.

part of river and lake systems whose water levels are partially controlled by power dams located downstream from the marshes. None of the marshes has been burned or grazed by livestock.

The amount of open water varies from 10 to 40 per cent and averages 11.5 per cent. During spring and summer the surface water varies in depth from one foot to two feet and averages 1.3 feet. In fall and winter, water levels vary from zero to 1.0 foot and averages 0.5 foot. All of the marshes freeze solidly in winter.

The principal vegetation of value to muskrats is arrowhead (*Saggitaria*), bur reed (*Sparganium*), cattail (*Typha*) and sweet flag (*Acorus*).

In the case of one of the marshes, the landowner's entire acreage was ditched. In the other two marshes, only part of the acreage was so treated. Data on area, ditching and costs are presented in Table 1.

All of the ditches were dug with power equipment, either drag-lines or clam-shell buckets. In all cases the earth removed from the ditch was placed in a continuous spoilbank parallel and immediately adjacent to the ditch.

The distance between ditches varies from 410 to 600 feet and averages 503 feet. In the ditched area, the number of linear feet of ditch per acre of marsh varies from 75 to 166 and averages 110. Cost of construction varied from 20 to 30 cents and averaged 24.6 cents per linear foot of ditch.

Most of the trapping in the ditched portions of the marshes is done by placing traps on boards floating in the ditches. It is seldom necessary to leave the boat to harvest the crop. In the unditched portions of the marshes trapping must be done on foot, setting the traps in runways.

TABLE 1.—AREA OF MARSHES, AREA DITCHED, DIMENSIONS AND COST OF DITCHES AND TIME OF CONSTRUCTION

Marsh Number	Total Area	Area Ditched	Dimensions of Ditches			Cost Totals	Year Ditched
			Length	Width	Depth		
	Acres	Acres	Feet	Feet	Feet	Dollars	
1	300	80	7,190	20	3	1,425	1940
2	50	50	8,300	20	4	2,000	1938
3	659	113	8,466	12	4	2,540	1938
Totals	1,009	243	36,656			5,965	

NUMBER OF MUSKRATS TRAPPED

The average number of muskrats trapped before ditching was 1.3 per acre per year. After ditching, the average number trapped was 3.8 per acre per year.

The number of muskrats trapped from each marsh for an equal number of years before and after ditching is given in Table 2.

ECONOMIC ANALYSIS

Marsh land of the type described here could be purchased for $10.00 per acre during the period 1935–45. The average cost of ditching, as reported by the landowners, was $24.54 per acre.

Under Wisconsin law, licensed musk-

TABLE 2.—NUMBER OF MUSKRATS TRAPPED ANNUALLY FOR AN EQUAL NUMBER OF YEARS BEFORE AND AFTER DITCHING ON THREE MARSHES

Year	Marsh Number			
	1	2*	3	
1930–31			237	
1931–32		200	—	
1932–33		200	345	
1933–34		200	536	
1934–35	150	200	383	
1935–36	859	122	490	
1936–37	513	160	106	
1937–38	89	513	861	
1938–39	567	975	958	
1939–40	2,078	929	1,576	
1940–41	2,595	783	1,019	
1941–42	2,922	1,643	1,638	
1942–43	2,198	750	2,264	
1943–44	1,248	226	2,304	
1944–45	109	389	203	
1945–46	743	—	—	Total
Avg. before ditching	709	228	422	1,359
Avg. after ditching	1,636	814	1,423	3,863

* Actual records of the number of muskrats trapped on Marsh 2 for the years 1931–32 through 1934–35 were not available. The figures used are the owner's estimate.
Bold-faced figures represent years after ditching

rat farmers buy the estimated muskrat population on their licensed land from the State at 50 cents per muskrat. These marsh owners estimated they trapped 71 per cent of the total population. Therefore, this cost was computed as follows: Average catch before ditching $1,359 \div .71 \times \$0.50 =$ Cost of original stock.

Four types of annual expenses were considered: non-cash expenses (labor and equipment depreciation), cash expenses (annual license and tags), taxes, and interest.

Labor required for trapping in a marsh after ditching was reported to be one man-hour per 7.3 muskrats caught. This rate, 0.14 man-hours per muskrat caught, compares favorably with the rate (0.18 man-hours) reported by Aldous (1947) for a similar type of trapping. No good record of the labor

TABLE 3.—CAPITAL INVESTED IN 1,009 ACRES OF MARSH BEFORE AND AFTER DITCHING

	Before	After
Land	$10,090.00	$10,090.00
Ditching		5,965.00
Original stock of muskrats	957.00	957.00
Total	$11,047.00	$17,012.00

TABLE 4.—ANNUAL EXPENSES IN THE OPERATION OF 1,009 ACRES OF MARSH BEFORE AND AFTER DITCHING

	Before		After	
Labor @ $0.50 per hour	$147.50		$419.00	
Equipment depreciation	12.08		34.30	
Total, Non-cash expense		$159.58		$ 453.30
Annual license	69.95		69.95	
Tags	13.59		38.63	
Total, Cash expense		83.54		108.58
Taxes		121.08		163.62
Interest (4% of capital investment)		441.88		680.48
Total annual expense		$806.08		$1,405.98

required for trapping marshes before ditching was available. For this reason the same rate was used as for trapping after ditching. As a result the labor charges in the "Before" column of Table 4 are probably too low and the net income and return per hour of labor in the "Before" column of Table 5 are too high. Labor required for skinning, stretching and fleshing was reported as one man-hour per 12.5 muskrats handled, assuming a skillful operator who wanted to do a good job.

Equipment depreciation includes traps and stretching boards. Traps were figured at one for each three muskrats caught, the total number being made up of one-third stop-loss traps at 75 cents each and two-thirds No. 1½ steel traps at 35 cents each. Stretching boards were figured at 5 cents each, one for each three muskrats caught. Both traps and stretching boards were estimated to have a 20-year life with good care.

Annual license fees in Wisconsin are computed on an acreage basis: $2.50 for the first 10 acres, 15 cents per acre for the next 30 acres, 10 cents per acre for the next 40 acres, and 5 cents per acre for any additional acreage.

All pelts marketed from a licensed muskrat farm in Wisconsin must be tagged with a tag furnished by the conservation department at a cost not to exceed one cent each. Taxes were computed on the basis of local tax rates for valuations of $10.00 per acre for unditched marshland and $25.00 per acre

TABLE 5.—ANNUAL NET INCOME FROM 1,009 ACRES OF MARSH BEFORE AND AFTER DITCHING

	Before	After
Income from sale of pelts	$1,997.73	$5,678.61
Total expense (from Table 4)	806.08	1,405.98
Net income	$1,191.65	$4,272.63
Per acre	$ 1.18	$ 4.23
Rate of interest earned on capital*	14.8%	29.1%
Return per hour of labor†	$ 4.54	$ 5.60

* Net income + interest charge (Table 4) ÷ Capital invested (Table 3) × 100.
† Net income + labor charge (Table 4) ÷ man-hours of labor.

for ditched marshland.

None of the ditches has been in operation long enough to indicate what maintenance costs may be expected. Observations indicate that ditches in marshes subject to flooding by silt-carrying streams may require a clean-out in 10 to 15 years. No accurate estimate of this cost could be made.

Income from the sale of pelts was computed by multiplying the average annual catch by $1.47, the average price per pelt received during the period 1935–1945.

Of special interest to landowners contemplating this type of marsh improvement is the fact that the *additional* net income after ditching was enough to completely liquidate the investment in *two years*.

No attempt was made to determine the influence of level ditching on other species of furbearers. It is interesting to note, however, that one of the marsh owners who kept careful, accurate records reported taking pelts of beaver, mink, raccoon, and weasel having a gross value of $1.41 per acre. Being conservative, one could easily add $1.00 per acre to the net return.

DISCUSSION

The marsh owners believe that level ditches result in an increased catch of muskrats for three reasons. First, they hold water of sufficient depth to prevent solid freezing in the winter. This provides muskrats with access to food plants and prevents the annual mid-winter "run" which takes place when shallow marshes freeze solid. In other words, it stabilizes the winter population and holds the muskrats on the marsh.

Second, the spoilbanks again prevent migration and drowning losses by providing the muskrats with a safe place to live during spring floods. The spoilbanks also provide den sites.

Third, the ditches apparently provide a better environment for important muskrat food plants than the marsh itself.

A comparison of the muskrat catch on ditched and unditched marshes would be most useful to land owners and managers. Since separate records were not kept of the number of muskrats taken from the ditched and unditched portions of the marsh, such a comparison must await additional data.

SUMMARY AND CONCLUSION

The study of three Wisconsin marshes, in which the owners had constructed level ditches between 1938 and 1940 demonstrated that on peat and muck marshes having low water levels (0.5 feet in winter) in east-central Wisconsin, level ditching on less than 25 per cent of the total marsh area resulted in:

(a) An increase of 2.5, or 192 per cent in the number of muskrats caught per acre per year.
(b) An increase of $3.05, or 259 per cent in the net return per acre per year.
(c) An increase of 97 per cent in the rate of interest earned on capital investment in spite of an increase of 54 per cent in the amount of capital invested.
(d) An increase of $1.06, or 23 per cent in the return per hour of labor spent in trapping, skinning, stretching and fleshing muskrats.

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MUSKRAT INVESTIGATIONS ON THE BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Herbert L. Dozier, Merle H. Markley and Leonard M. Llewellyn[1]

United States Department of the Interior, Fish and Wildlife Service, Cambridge, Maryland

The muskrat (*Ondatra zibethicus*) has been one of the chief factors in maintaining a high total value for our annual fur production. Muskrat fur is an established commodity which is consumed in tremendous quantities by the fur trade. In commercial importance it heads the list of raw fur produced in the United States, the yearly take being approximately 20,000,000 pelts.

Muskrats multiply more rapidly than other wild fur animals and because of their aquatic retreats and general habits, are better fitted to maintain their numbers under reasonable protection. Then too, their extensive range which includes every state except Florida gives them added advantage in maintaining their numbers.

More than 200,000 muskrat pelts are taken annually on the 50 Federal Wildlife Refuges now producing annual crops of fur in commercial quantities. Beaver, fox, mink, opossum, otter, raccoon, skunk and weasel are other fur animals produced on these Federal lands.

One hundred thousand dollars was returned to the Treasury of the United States from the sale of furs produced on Federal refuges during 1946–47. Approximately an equal amount was received by the trappers for their services and the counties in those states where the refuges are located received 25 per cent of this amount.

In order to improve fur animal management, methods are being devised for estimating populations, numbers of animals to be trapped annually, areas to be trapped, best method of trapping, and pelting, drying, grading, packing and shipping of raw furs. Information is also required on the effects of impoundments and land management practices on muskrats and other fur animals.

This paper reports the results of a five-year study in connection with trapping operations on the Blackwater National Wildlife Refuge in Maryland. Some data that were secured during the 1941 and 1942 trapping seasons have been previously published (Dozier and Allen, 1942; Dozier, 1944). The present paper gives an analysis of all data obtained during the entire period, 1941–1945. The data have been recorded separately for each of the 27 trapping units, consisting of a total of 5,233 acres of tidal marsh. Boundaries of these

[1] The authors are indebted to the following personnel of the Fish and Wildlife Service: Frank G. Ashbrook for helpful direction and critical review of this manuscript; to Cornelius W. Wallace for cooperation in obtaining records of annual catches of muskrats; and Francis Uhler for valuable data on marsh plant tolerance with respect to degree of salinity. Thanks are due Charles E. Kellogg and David V. Black formerly of the Fish and Wildlife Service for their assistance and cooperation in this research study.

"hunts" have been maintained intact in order to obtain comparative information on color, sex ratio of adults and young, average weights, abundance and types of food.

Over the five-year period a total of 23,539 muskrats has been taken during the Maryland legal muskrat trapping season, January 1 to March 15. Of these, 23,511 of the catch were found to be in suitable condition for accurately sexing and weighing. Due to the extreme difficulty of accurately distinguishing, by external examination only, the large subadults from the small adults such a segregation has not been found entirely satisfactory or practical.

During the first three years, trapping was conducted intensively on a commercial scale on all of the 27 designated units of the refuge. Due to the subsequent low level of the muskrat population and scarcity of desirable trappers under war time labor conditions, trapping during the last two years was conducted on only a few units, selected for securing further experimental data.

SEX RATIO

During these investigations 13,421 males and 10,090 females were carefully sexed by a check of the external genitalia. The preponderance of 57 per cent males or ratio of 133 males per 100 females was significant. This distinct excess of males over females was consistently maintained during each of the trapping seasons involved, varying from 56 to 62 per cent or a ratio of 127 to 163 males per 100 females. There is a common belief among local trappers and those of many other sections of the country that more females are taken during the latter part of the trapping season; also that the greater activity and wandering tendencies of the male at certain periods might easily lead to some selectivity in trapping results. Both are clearly refuted by the data given in Table 1, presented in bi-weekly periods, which shows that a five-year average catch of 57 per cent males was taken during the final 15 day period of the legal trapping season (March 1–15).

A table summarizing all available muskrat sex ratio references was given by Dozier and Allen (1942). All but one of these showed a preponderance of males and this fact has been further confirmed by more recent investigations. Hewitt (1942) found 52.7 per cent males or a ratio of 112 males per 100 females in 6,351 muskrats from a 1,600 acre marsh in southern Ontario in 1938 and an identical ratio in the following season's catch of 7,815. The sex was accurately determined as each carcass was dressed. Baumgartner and Bellrose (1943) reported 51.8 per cent males in a total of 8,107 individuals of *Ondatra z. zibethicus* from Michigan and 48.8 per cent males in 2,090 from Rice and Chautauqua Lakes in Illinois. Highby (1943) gave a ratio of 134 males per 100 females in 3,045 muskrats from the vicinity of St. Paul and Minneapolis, Minnesota and Sooter (1946) 55 per cent males or a ratio of 122 males per 100 females among 1,530 adult and subadults of presumably the same race taken at Tule Lake Refuge, California. Anderson (1947) reports 55.2 per cent males or a ratio of 124 males per 100 females in a total of 5,759 muskrats from southwestern Lake Erie in Ohio. Observations by Lay (1945) on 1,168 muskrats, *Ondatra z. rivalicius*, from the southeastern Texas coast showed 59.2

TABLE 1.—THE ANNUAL CATCH AND SEX RATIO OF MUSKRATS ON THE BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Period	1941				1942				1943				1944				1945				Summary			
	Catch		% ♂♂	♂♂ per 100 ♀♀	Catch		% ♂♂	♂♂ per 100 ♀♀	Catch		% ♂♂	♂♂ per 100 ♀♀	Catch		% ♂♂	♂♂ per 100 ♀♀	Catch		% ♂♂	♂♂ per 100 ♀♀	Catch		% ♂♂	♂♂ per 100 ♀♀
	♂♂	♀♀			♂♂	♀♀			♂♂	♀♀			♂♂	♀♀			♂♂	♀♀			♂♂	♀♀		
Jan. 1–15	1,546	1,250	55	122	646	444	60	150	562	435	56	127	148	113	58	138	374	273	58	138	3,276	2,515	57	133
16–31	1,703	1,253	58	138	1,128	785	59	144	521	373	58	138	174	103	63	170	216	175	55	122	3,742	2,689	58	138
Feb. 1–15	667	588	53	113	634	498	56	127	834	583	59	144	65	45	59	144	313	244	56	127	2,513	1,958	56	127
16–28	432	417	51	104	561	410	58	138	181	141	56	127	191	96	67	203	232	154	60	150	1,597	1,218	57	133
Mar. 1–15	962	743	56	127	893	598	60	150	228	213	52	108	84	42	67	203	126	114	53	113	2,293	1,710	57	133
Totals	5,310	4,251	56	127	3,862	2,735	59	144	2,326	1,745	57	133	662	399	62	163	1,261	960	57	133	13,421	10,090	57	133

Total number of muskrats sexed for five year period—23,511.

per cent males or a ratio of 145 males per 100 females. Aldous (unpublished) found 56.4 per cent males in a total of 1,249 *Ondatra z. cinnamominus*, taken on the Sand Lake National Wildlife Refuge in South Dakota from Nov. 1, 1944 to Jan. 31, 1945.

COLOR RATIO

Two common color phases occur in the Coastal or Virginia muskrat throughout most of its range. These are usually referred to as "browns" or "reds" and "blacks," the former generally predominating although there is considerable local variation in relative abundance.

Earlier printed references to "black" muskrats in this race actually indicated a black-and-tan mutation, phenotypically the same as that reported occurring in other rodents such as the house mouse, *Mus m. musculus*, and Norway rat, *Rattus norvegicus*. For the sake of brevity, in this paper the authors adhere to the term "black," but in reality this refers to what is genetically known as black-and-tan (symbol, a^t).

Dozier (1944) has shown that statistically there were no significant sexual differences in color ratios in 6,343 adults and subadults from the 1942 Blackwater Refuge catch. Therefore, it has not been deemed necessary to present in this paper such a color ratio by sexes. Table 2 gives the actual number and per cent by color of all muskrats taken during each of the five years.

Considerable variation in numbers of black and brown individuals is evident from year to year and even from adjacent trapping units. Locally, marshes are rather frequently referred to as

TABLE 2.—MUSKRAT COLOR RATIO, BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Trapping Season	Number			% Black
	Black	Brown	Total	
1941	5,125	4,458	9,583	*53*
1942	3,387	3,211	6,598	*51*
1943	2,184	1,889	4,073	*54*
1944	541	520	1,061	*51*
1945	1,094	1,130	2,224	*49*
Totals	12,331	11,208	23,539	*52*

being "red" or "black," depending on the predominating color phase present. According to many of the older marsh owners and trappers a considerable fluctuation has taken place in their years of experience. For the refuge as a whole blacks have predominated slightly over browns during four of the five years under consideration (1941–1945), the number varying from 49 to 54 per cent of the annual catch. A summary for the five year period gives a ratio of 52 per cent black to 48 per cent brown.

WEIGHTS

Except for a limited number of individuals that were partly eaten by predators and scavengers while in the traps, weights were obtained on all muskrats trapped on the Blackwater Refuge during 1941–1945. The weighing was done with a Chatillon hand or spring-scale, reading in pounds and ounces. Most of the animals were weighed within 24 hours after being caught, but a comparatively few remained frozen in the traps for several days before being weighed. They were weighed as soon as possible after being brought in from the trap-lines and were usually slightly damp. Only a small number were wet enough to affect the weight, and these were scattered about equally among the sexes, so that it is believed that they made no significant difference in the results.

Average weights are given on a total of 23,511 muskrats in Table 3, arranged according to sex and date of trapping. As previous studies at this station have shown no significant differences between color phases with respect to average weights, these are given only by sex. The 13,421 males ranged from 6 ounces (170 g.) to 4 pounds (64 oz., 1,814 g.), the average being 2 pounds 4 ounces (36 oz., 1,030 g.). Among the 10,090 females, the extremes were 6 ounces (170 g.) to 3 pounds 12 ounces (60 oz., 1,701 g.), and the average weight was 2 pounds 2 ounces (34 oz., 962 g.). The long season for reproduction under Maryland conditions may result some years in considerable late breeding and production of fall "kits." This fact would undoubtedly reduce the general weight average obtained at trapping time.

Although the average combined weights of both sexes have shown remarkably little variation from year to year, there has always been a distinct sexual difference in weights, the males averaging 6.6 per cent (2.4 oz., 68 g.) heavier than the females. This disparity has been maintained consistently over the entire five-year period for large samples of both young and adults and therefore appears significant. Dozier (1945) states that "accurate comparisons between weights of muskrats from different sections of the country cannot be made unless the amount of fat is

PLATE 3.—*A*. An over-populated Maryland brackish-water marsh, *Scirpus olneyi*, showing the beginning of a bad "eat-out" by muskrats. *B*. Scarcity of muskrat houses in cordgrass formation, *Spartina alterniflora*, typical of the more saline tidal marshes.

TABLE 3.—AVERAGE WEIGHTS (IN POUNDS) OF MUSKRATS ON THE BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Period	1941			1942			1943			1944			1945			Summary		
	♂♂	♀♀	Combined	♂♂	♀♀	Combined	♂♂	♀♀	Combined	♂♂	♀♀	Combined	♂♂	♀♀	Combined	♂♂	♀♀	Combined
Jan. 1–15	2.23	2.14	2.19	2.22	2.03	2.15	2.16	2.04	2.11	2.21	2.04	2.14	2.30	2.10	2.21	2.22	2.10	2.16
16–31	2.27	2.15	2.22	2.28	2.14	2.22	2.25	2.05	2.17	2.29	2.12	2.23	2.43	2.16	2.31	2.28	2.13	2.22
Feb. 1–15	2.27	2.14	2.21	2.31	2.22	2.27	2.33	2.19	2.27	2.30	2.12	2.21	2.38	2.19	2.30	2.32	2.18	2.26
16–28	2.31	2.11	2.21	2.29	2.16	2.23	2.20	2.05	2.13	2.31	2.23	2.28	2.23	2.13	2.19	2.28	2.13	2.22
Mar. 1–15	2.26	2.10	2.19	2.26	2.06	2.18	2.15	2.01	2.08	2.29	2.13	2.24	2.22	2.10	2.16	2.25	2.08	2.18
Totals	2.26	2.13	2.20	2.27	2.12	2.21	2.24	2.09	2.18	2.28	2.13	2.22	2.32	2.14	2.24	2.27	2.12	2.21

Total number of muskrats for five year period—23,511.

considered." Apparently, this depends on the amount and quality of food present rather than to geographical location. In this connection he has pointed out the great contrast in degree of fat present on muskrats from the Montezuma marshes of central New York with those from the Blackwater Refuge in Maryland where muskrat carcasses have consistently shown a remarkably small amount of fat throughout many years of observation.

A general increase in average weights of both sexes occurred up until February 15. Following this indicated peak of physical development, a rather rapid decline in weight took place, due possibly to warmer weather and the approach of the mating season.

SEASONAL FLUCTUATION IN TRAPPING RESULTS

A study of the annual muskrat catch on the Refuge, arranged by bi-weekly and monthly periods in Table 4, brings out the important fact that from 45.5 to 60 per cent of the catch each year (53 per cent average—1941–1945) occurred during January, the first month of the 10-week Maryland legal trapping season. This was due invariably to better water conditions, contingent largely on wind and tide, and to milder weather usually prevailing at that time. The five-year study has shown January 16–31 to be the most productive period, accounting for 27 per cent of the average catch and February 16–28 the least productive with only 12 per cent. It is interesting to note that muskrats of maximum average weight and pelt size, and also of good quality, were caught in between these two periods. In this section, muskrats generally reach their

TABLE 4.—PERCENTAGE OF THE TOTAL MUSKRAT CATCH IN BI-WEEKLY AND MONTHLY PERIODS, BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Period	1941		1942		1943		1944		1945		Summary	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Jan. 1–15	2,796	*29*	1,090	*16.5*	997	*24*	261	*25*	647	*29*	5,791	*25*
16–31	2,956	*31*	1,913	*29*	894	*22*	277	*26*	391	*18*	6,431	*27*
Jan. 1–31	5,752	*60*	3,003	*45.5*	1,891	*46*	538	*51*	1,038	*47*	12,222	*52*
Feb. 1–15	1,255	*13*	1,132	*17*	1,417	*35*	110	*10*	557	*25*	4,471	*19*
16–28	849	*9*	971	*15*	322	*8*	287	*27*	386	*17*	2,815	*12*
Feb. 1–28	2,104	*22*	2,103	*32*	1,739	*43*	397	*37*	943	*42*	7,286	*31*
Mar. 1–15	1,705	*18*	1,491	*22.5*	441	*11*	126	*12*	240	*11*	4,003	*17*
Totals	9,561	*100*	6,597	*100*	4,071	*100*	1,061	*100*	2,221	*100*	23,511	*100*

best prime condition during the last two weeks of February. Unfortunately, this period also yielded the smallest number of pelts.

Trapping success is to a very great extent dependent upon weather conditions, for heavy ice formation, deep snows or marked daily tidal fluctuations in the case of our coastal marshes, seriously hamper trapping operations and often keep local trappers out of their marsh units for days at a time. Milder weather towards the end of the trapping season may often be completely offset by adverse water conditions.

LATE SUMMER AND FALL LITTERS

Although the preceding data represent the entire catch, all young that were evidently from late summer- or fall-produced litters have been separately recorded as a "kit" class that corresponds closely with such a grading by local fur buyers. Normally in this section litter production ceases about October 10. The occasional unusually small, so-called "mice" therefore unquestionably represent the result of what has been termed by the senior author "out-of-season" breeding. In order to insure uniformity of records with data presented in previous publications, all young weighing 1 lb. 6 ozs., or less have been arbitrarily classified as kits. It is clearly realized that weight alone is not an infallible criterion for age classification. However, such a grouping does give an excellent indication as to late summer and fall litter production and survival of young.

Of the total catch of 23,539 muskrats for the five-year period, only 1,038 or 4.4 per cent, were classified as kits, with a variation of three to five per cent from

year to year. Of all kits trapped, 488 or 47 per cent were males and 547 or 53 per cent females, a ratio of 89 males per 100 females. During four of the five trapping seasons involved kit females outnumbered the males from 52 to 57 per cent, the reverse of the adult ratio which showed a consistent and significant preponderance of males. This lends further support to the possibility pointed out by Dozier (1944) that the sex ratio among trapped adult muskrats is not the same as that which might occur at birth, and is in agreement with the statement by Lay (1945) that age group ratios by sex show an increase in the proportion of males with increasing age.

Data obtained on the annual and total kit catches substantiate the fact that there is an appreciable difference in color ratio between that group and the older animals although this is apparently not very great. Kits showed a slightly higher ratio of black individuals as compared with the combined subadult and adult population. During the five-year study black kits outnumbered brown in a ratio of 54 to 46 per cent, and varied from 52 to 59 per cent in different seasons. According to Dozier (1944) there is a common belief among Maryland trappers who have handled large numbers of live muskrats that the brown phase is hardier and can stand more abuse than the black. Both the annual catch data and the five year summary would seem to indicate a slightly higher survival rate for the browns. Black kits consistently exceeded black adults, showing that a decrease in the proportion of blacks actually took place as maturity was approached.

VARIATION IN MARSH PRODUCTIVITY

As brought out by Dozier (1947) a steady rise in the muskrat population took place on the Blackwater Refuge until a peak was reached in 1938, when a maximum catch of 26,286 was trapped, an average yield of 5.02 muskrats per acre of marsh. A total of 27,373 houses was counted on the area for the same season, giving a catch of only 1.04 muskrats per house. A steady decline in the population followed until conditions became so bad in 1944 that it was deemed inadvisable to trap the major portion of the Refuge. In 1943, the last season in which the entire acreage was trapped, a catch of 4,170 muskrats or a yield of 0.80 per acre was obtained. The 6,250 houses counted for that season gave only 0.67 animals trapped per house. The prolonged drouth throughout the summer and fall of 1943 resulted in a radical reduction in the number of houses counted that November. In 1944 only five units, with a total count of 1,008 houses, were trapped for experimental purposes in order to obtain continuous comparative data. A total of 1,061 muskrats was taken that year, a yield of only 1.28 per acre or 1.05 per house. The number of units experimentally trapped was increased in 1945 to six, on which 1,136 houses were counted. A total of 2,261 muskrats was trapped that year, a yield of 2.66 per acre or 1.99 per house.

It is evident therefore that the peak year of muskrat abundance gave a decidedly higher return in terms of yield per acre but a lower catch per house. This is probably due to the more intensive trapping necessary during years of scarcity in order to obtain economically worthwhile returns. While the

TABLE 5.—DATA ON ANNUAL MUSKRAT DENSITY, YIELD AND AVERAGE WEIGHT BY TRAPPING UNITS, B

Unit	Acres	1941						1942						1943			
		Houses	Catch	Houses per Acre	Yield per Acre	Yield per House	Average Weight	Houses	Catch	Houses per Acre	Yield per Acre	Yield per House	Average Weight	Houses	Catch	Houses per Acre	Yield per Acre
1	219	193	288	0.88	1.32	1.49	2.38	377	235	1.72	1.07	0.62	2.34	299	265	1.37	1.21
2	196	242	269	1.23	1.37	1.11	2.38	293	317	1.49	1.62	1.08	2.44	100	308	0.51	1.57
3	171	474	203	2.77	1.19	0.43	2.31	305	322	1.78	1.88	1.06	2.43	214	223	1.25	1.30
4	156	466	481	3.00	3.08	1.03	2.39	422	354	2.70	2.27	0.84	2.33	272	404	1.74	2.59
5	141	613	363	4.35	2.57	0.59	2.36	309	172	2.19	1.22	0.56	2.30	135	81	0.96	0.57
6	202	333	394	1.65	1.95	1.18	2.26	304	253	1.50	1.25	0.83	2.29	265	216	1.31	1.07
7	138	191	243	1.38	1.76	1.27	2.31	293	313	2.12	2.27	1.07	2.34	165	121	1.20	0.88
8	98	271	292	2.77	2.98	1.08	2.12	139	295	1.42	3.00	2.12	2.33	95	227	0.97	2.32
9	111	437	313	3.94	2.82	0.72	2.15	364	187	3.28	1.68	0.51	2.13	328	135	2.96	1.22
10	193	272	603	1.41	3.12	2.22	2.19	287	539	1.49	2.79	1.88	2.17	496	497	2.57	2.58
11	155	252	164	1.63	1.06	0.65	2.15	140	77	0.90	0.50	0.55	2.12	69	31	0.45	0.20
12	132	275	242	2.08	1.83	0.88	2.23	241	391	1.83	2.96	1.62	2.14	143	46	1.08	0.35
13	342	363	167	1.06	0.49	0.46	2.16	118	192	0.35	0.56	1.63	2.10	104	13	0.30	0.04
14	137	418	427	3.05	3.12	1.02	2.18	254	190	1.85	1.39	0.75	2.11	267	274	1.95	2.00
15	182	515	644	2.83	3.54	1.25	2.14	428	395	2.35	2.17	0.92	2.06	421	192	2.31	1.05
16	215	865	567	4.02	2.64	0.66	2.37	268	686	1.25	3.19	2.56	2.17	730	174	3.40	0.81
17	127	497	512	3.91	4.03	1.03	2.13	166	313	1.31	2.46	1.88	1.93	92	196	0.72	1.54
18	323	567	367	1.75	1.14	0.65	2.01	9	29	0.03	0.09	3.22	1.97	27	19	0.08	0.59
19	279	125	542	0.45	1.94	4.34	2.13	65	125	0.23	0.45	1.92	1.95	108	33	0.39	0.12
20	248	662	211	2.67	0.85	0.33	2.30	457	144	1.84	0.58	0.32	2.15	505	59	2.04	0.24
21	495	645	215	1.30	0.43	0.33	2.32	444	226	0.90	0.46	0.51	2.27	468	89	0.95	0.18
22	232	392	381	1.69	1.64	0.97	2.21	123	154	0.53	0.66	1.25	2.29	51	54	0.22	0.23
23	227	686	318	3.03	1.40	0.46	2.36	154	302	0.68	1.33	1.96	2.27	134	29	0.59	0.13
24	113	434	701	3.84	6.20	1.61	2.37	137	195	1.21	1.72	1.42	2.21	294	158	2.60	1.40
25	92	406	447	4.41	4.96	1.10	2.24	146	92	1.59	1.00	0.63	2.20	189	25	2.05	0.27
26	202	447	349	2.21	1.73	0.78	2.19	162	97	0.80	0.48	0.60	2.14	138	78	0.68	0.39
27	107	138	193	1.29	1.80	1.40	2.40	155	239	1.45	2.23	1.54	2.35	141	223	1.32	2.08
	5,233	11,175	9,895	2.13	1.83	0.89	2.20	6,560	6,735	1.25	1.29	1.03	2.21	6,250	4,170	1.19	0.80

number of muskrats actually inhabiting a house may remain approximately the same in years of both abundance and scarcity yet during the latter period the distribution of the houses is generally very uneven or "spotty." Much more effort and time is required therefore on the part of the trapper to cover his assigned units or acreage which in many cases may have been doubled or even trebled in seasons of scarcity to make sufficiently profitable "hunts."

Although the total yield of 26,286 muskrats in the peak year of abundance in 1938 was considered highly satisfactory for the Refuge as a whole this figure represents actually only a fair to average trapping efficiency (1.04 per house). Trapping ability and energy of the individual varies widely. Although this is recognized as a most important factor it is one that cannot be easily controlled or properly evaluated. On many units, the population density was so great that the trapper simply could not cover the assigned area thoroughly enough in the allotted time with the average number of traps available to him. This under-trapping resulted in some very bad "eat-outs" (see Plate 3A) of which present-day Rhode Island (No. 18), McGraw Island (No. 19), Deadwoods (No. 16) and Sunken Island (No. 23) marshes are representative. It will take many more years for the vegetation on these units to come back to its former state of luxuriant growth and muskrat production. The manner in which "eat-outs" originate and their seriousness is thoroughly discussed in detail by Lynch, O'Neil and Lay (1947).

There appears to be a direct correlation between the degree of marsh salin-

TRAPPING UNITS, BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

1943				1944						1945					
Yield per Acre	Yield per House	Average Weight	Houses	Catch	Houses per Acre	Yield per Acre	Yield per House	Average Weight	Houses	Catch	Houses per Acre	Yield per Acre	Yield per House	Average Weight
1.21	0.89	2.29	265	148	1.21	0.68	0.56	2.33	184		0.84			
1.67	3.08	2.23	152		0.78				74		0.38			
1.30	1.04	2.25	62		0.36				92		0.54			
2.59	1.49	2.16	46		0.29				61		0.39			
0.57	0.60	2.31	63		0.45				71		0.50			
1.07	0.82	2.14	167	88	0.83	0.44	0.53	2.17	119	177	0.59	0.88	1.49	2.44
0.88	0.73	2.13	101		0.73				146	77	1.06	0.56	0.49	2.45
2.32	2.49	2.14	81		0.83				91	492	0.93	5.00	5.41	2.19
1.22	0.41	2.22	243	108	2.19	0.97	0.44	2.05	308	896	2.77	8.08	2.91	2.17
2.58	1.00	2.11	234	461	1.21	2.39	1.97	2.16	380	468	1.97	2.42	1.23	2.32
0.20	0.45	2.01	37		0.24				15		0.10			
0.35	0.32	2.32	35		0.27				30		0.23			
0.04	0.13	2.00	90		0.26				99		0.29			
2.00	1.03	2.12	48		0.35				42		0.31			
1.05	0.46	2.04	68		0.32				87		0.48			
0.81	0.24	2.40	127		0.59				134		0.62			
1.54	2.13	1.90	29		0.23				20		0.16			
0.59	0.70	1.80	0		0.00				1		0.00			
0.12	0.31	1.83	10		0.04				24		0.09			
0.24	0.12	2.12	201		0.81				152		0.61			
0.18	0.19	2.17	76		0.15				42		0.08			
0.23	1.06	2.16	48		0.21				32		0.14			
0.13	0.22	2.00	39		0.17				22		0.10			
1.40	0.54	2.16	94		0.83				82		0.73			
0.27	0.13	2.71	107		1.16				40		0.43			
0.39	0.57	2.04	53		0.26				42		0.21			
2.08	1.58	2.37	99	256	0.93	2.39	2.59	2.36	92	156	0.86	1.46	1.70	2.43
0.80	0.67	2.18	2,575	1,061	0.49	1.28	1.10	2.22	2,482	2,266	0.47	2.66	0.90	2.24

ity and the growth and abundance of the preferred food plants of the muskrat. The vegetation of the Blackwater Refuge is typical of tidal marshes that border the lower Chesapeake Bay, ranging from those of a fresh or slightly brackish ecological type, such as cattails, *Typha* spp., three-square sedges, *Scirpus americanus, olneyi,* and *robustus,* and tall reed, *Phragmites communis,* along the upland wooded borders and the upper reaches of the creeks and rivers, into a more brackish salt marsh of needlegrass, *Juncus roemerianus,* saltmarsh cordgrass or "blade grass," *Spartina alterniflora,* and saltmeadow grass, *Spartina patens.* Extensive stands of big cordgrass, *Spartina cynosuroides,* occur particularly along the banks of the meandering rivers. The nature of most of these marshes is such that they are open and subject to the ebb and flow of the tide, being bathed directly by tidal fluctuations of river water, subject to seasonal variation in degree of salinity.

From comparative analysis of the data presented in Table 5, covering the 27 trapping units, the following deductions are evident:

1. Units 16 and 12 are "fresh-water" marshes. They are least subject to any tidal action and therefore are the freshest points to be found on the entire Refuge. The vegetation consisted of *Scirpus olneyi* and *S. americanus,* with large stands of *Typha* spp. The water supply on these units is almost entirely dependent on rainfall and the run-off from the adjoining woods. In spite of the rather dry summer of 1941, the muskrat population increased that year on these units. The more intense and

prolonged drouths of 1943 and 1944, however, caused these almost to dry up, with most disastrous effect on both vegetation and muskrats.

2. Units 1, 2, 3, 4, 8, 9, 10 and 27 had a fairly high sustained yield. These were slightly brackish units with the vegetation entirely *Scirpus olneyi* and *Typha* spp.

3. Units 5, 6, 7, 14 and 15 yielded well during 1941 but exhibited a rather steady downward trend. All of these units are moderately brackish and consisted of 50 per cent or more of *Scirpus olneyi*, with the remainder *Juncus roemerianus* or *Spartina patens*.

4. Units 18, 19, 22, 23 and 26 showed an abrupt downward trend. All are distinctly brackish, consisting predominantly of *Spartina alterniflora* and *patens*, with less than 50 per cent *Scirpus olneyi*.

5. Units 11, 13, 20 and 21 have been consistently the least productive marshes, yielding in 1941 only 1.06, 0.49, 0.85 and 0.43 muskrats per acre respectively. These are the more saline units, with the vegetation consisting of *Spartina alterniflora* and *patens*, *Juncus roemerianus* and sparse *Scirpus olneyi*.

6. Units 24, 25 and 17 represented the three highest yielding marshes in 1941 that produced respectively 6.2, 4.96 and 4.03 muskrats per acre. The vegetation consisted of excellent *Scirpus olneyi* with some *Typha* spp. All three units were greatly influenced by fresh water run-off from the adjacent woodlands. The catch the following year declined abruptly to 1.7, 1.0 and 1.54 per acre respectively. This may have been caused by the greatly increased salinity, especially pronounced over the lower marshes, that resulted from the extremely dry summer of 1941.

CORRELATION OF WEIGHT WITH TYPE AND ABUNDANCE OF FOOD PLANTS

Weights for the refuge as a whole have been discussed previously under a separate heading, based on data presented in Table 3. Dozier and Allen (1942) have pointed out that there was a difference in weight of muskrats coming from various types of marsh on the Blackwater Refuge. Aldous (1947), in discussing size in relation to habitat, stated that pelt measurements of muskrats trapped on the Sand Lake National Wildlife Refuge, South Dakota, indicated that the largest animals were produced on those areas harboring the greatest concentrations of river bulrush, *Scirpus fluviatilis*, and reed, *Phragmites communis;* also that the size was slightly smaller in those areas where a large number of bank muskrats were normally present.

Data given in Table 6 shows that the *Scirpus olneyi—Typha* formation, represented by Groups I and II, produced muskrats of the highest average weight. Over the period trapped, the average combined weight for these two groups was 2.25 and 2.26 pounds respectively. These marshes also were the freshest or least brackish ones to be found on the Refuge. In contrast, Groups IV and V yielded muskrats of appreciably lower average weights, 2.16 and 2.20 pounds respectively. The vegetation on these marshes consisted mainly of *Spartina patens*, *S. cynosuroides*, and *S. alterniflora* with rather sparse stands of *Scirpus olneyi;* conditions were decidedly brackish or highly saline.

It is evident from the above comparison that there is a direct correlation between size and weights of muskrats and the quality and abundance of their food

TABLE 6.—MUSKRAT PRODUCTIVITY OF VARIOUS MARSH TYPES, BLACKWATER NATIONAL

TABLE 6.—MUSKRAT PRODUCTIVITY OF VARIOUS MARSH TYPES, BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND, 1941–1945

Unit	Acres	Marsh Type		Total		Average for Period Trapped			
		Dominant Vegetation	Degree of Salinity*	Houses	Catch	Houses per Acre	Yield per Acre	Yield per House	Average Weight
			GROUP I						
12	132	*Scirpus olneyi, Scirpus americanus, and Typha* sp.	Fresh (*0.0–5.0%*)	659	679	1.66	1.71	1.03	2.18
16	215			1,863	1,427	2.89	2.21	0.77	2.28
			GROUP II						
1	219	*Scirpus olneyi*, and *Typha* sp.	Slightly brackish (*5.0–10.0%*)	1,134	936	1.29	1.07	0.83	2.34
2	196			635	894	1.08	1.52	1.41	2.35
3	171			993	748	1.93	1.46	0.75	2.34
4	156			1,160	1,239	2.48	2.65	1.07	2.30
8	98			596	1,303	1.52	3.32	2.20	2.20
9	111			1,680	1,639	3.03	2.95	0.98	2.16
10	193			1,669	2,568	1.73	2.66	1.54	2.19
27	107			625	1,067	1.17	2.00	1.71	2.27
			GROUP III						
5	141	*Scirpus olneyi*, and *Juncus roemerianus*	Moderately brackish (*10.0–15.0%*)	1,057	615	2.50	1.45	0.58	2.34
6	202			1,188	1,127	1.18	1.12	0.95	2.26
7	138			795	754	1.44	1.37	0.95	2.31
14	137			939	891	2.28	2.17	0.95	2.15
15	182			1,364	1,231	2.50	2.25	0.90	2.10
			GROUP IV						
18	323	*Spartina patens, Spartina alterniflora, Scirpus olneyi*, and *Typha* sp.	Decidedly brackish (*15.0–25.0%*)	603	415	0.62	0.43	0.69	2.00
19	279			298	700	0.36	0.85	2.35	2.08
22	232			566	589	0.81	0.85	1.04	2.23
23	227			974	649	1.43	0.95	0.67	2.30
26	202			747	524	1.23	0.86	0.70	2.16
			GROUP V						
11	155	*Spartina patens, Spartina alterniflora, Scirpus olneyi*, and *Juncus roemerianus*	Highly saline (*25.0–43.0%*)	461	272	0.99	0.58	0.59	2.13
13	342			585	372	0.57	0.36	0.64	2.12
20	248			1,624	414	2.18	0.56	0.25	2.22
21	495			1,557	530	1.05	0.36	0.34	2.27
			GROUP VI						
17	127	*Scirpus olneyi, Spartina patens*, and *Typha* sp.	Moderately brackish (1941) to decidedly brackish (1942) (*10.0–25.0%*)	755	1,021	1.98	2.68	1.35	2.02
24	113			865	1,054	2.55	3.11	1.22	2.31
25	92			741	564	2.68	2.04	0.76	2.25

* Percentage of the salinity of average Atlantic Ocean water; figures given are those usually occurring during the normal growing season.

supply. This is further substantiated by a study of several badly "eaten-out" marshes that have shown a most significant progressive decrease in muskrat weights as the supply of food plants diminished, through the combined effect nothing but shallow ponds and mud flats. Muskrats were forced to migrate in large numbers elsewhere to survive. The population density of the area dropped to only 0.5 houses per acre that fall.

TABLE 7.—PROGRESSIVE DECREASE IN MUSKRAT DENSITY, YIELD AND AVERAGE WEIGHTS, AS AFFECTED BY OVER-POPULATION, BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND

Unit	Marsh	Trapping Season	Houses per Acre	Yield per House	Average Weight	Trapper's Rating
17	Wolf Pit	1941	3.9	1.0	2.13	Poor
		1942	1.1	1.8	1.93	Good
		1943	0.7	2.1	1.90	Good
18	Rhode Island	1941	1.8	0.7	2.01	Poor
		1942	0.03	3.2	1.97	Excellent
		1943	0.1	0.7	1.80	Good
19	McGraws Island	1941	0.5	4.3	2.13	Excellent
		1942	0.2	2.1	1.95	Good
		1943	0.4	0.3	1.83	Good
23	Sunken Island	1941	3.0	0.5	2.36	Poor
		1942	0.6	1.4	2.27	Fair
		1943	0.6	0.2	2.00	Poor

of over-population and inefficient trapping.

Units 17, 18, 19 and 23 have produced the smallest adult muskrats on the entire Refuge during the period of this study. It is quite evident that this was due to over-population which resulted in a radical reduction in available food supply and consequent serious "eat-outs."

In 1940, Units 18 and 19 had a heavy concentration of 6.05 houses per acre but these areas were badly under-trapped (0.36 yield per house) that year by the private owners who held trapping rights prior to operation by Fish and Wildlife Service personnel in 1941. As a result, the vegetation was so badly eaten out during the summer of 1940 that Unit 18, especially, became

On Units 17 and 23 there was still a density of 3.9 and 3.0 houses per acre in 1941. The low yield of 1.0 and 0.5 muskrats per house obtained that year, through inefficient trapping, resulted also in very serious "eat-outs" during the summer and a reduction in population density to only 1.1 and 0.6 houses per acre that fall, respectively.

In all cases of serious "eat-outs" studied, the average weights have shown a progressive reduction, undoubtedly due to an inadequate food supply.

MANAGEMENT PRINCIPLES

Certain principles that lead to a better understanding of marsh management have resulted from this study:

1. A direct correlation between size

and weights of muskrats and the quality and abundance of their food supply was found. Badly "eaten-out" marshes showed a most significant progressive decrease in weights as the available food diminished. A ruinous effect was produced on the marsh vegetation by overpopulation and under-trapping and such a combination must be avoided at all costs. Under Atlantic Coast tidewater conditions, when the muskrat density reaches one dwelling house per acre, trapping should be undertaken. A density of 2.5 dwelling houses per acre calls for immediate intensive trapping to prevent serious "eat-outs."

2. The "yield per house" was found to be a much better indicator of actual trapping efficiency than the "yield per acre." As the house density decreased, the trapping efficiency, as expressed in yield per house, generally increased. This was probably due to the more intensive trapping necessary during such years of muskrat scarcity in order to obtain economically worthwhile returns.

3. Muskrat production is largely dependant upon the type of vegetation and the water supply. There appears to be a direct correlation between the degree of marsh salinity and the growth and abundance of the preferred food plants of the muskrat as well as the yield per acre. The fresh to slightly brackish *Scirpus olneyi—Typha* spp. formation, adjacent to timbered areas, produced the largest yields of muskrats. On the lower marsh units approaching Chesapeake Bay, where conditions were decidedly brackish to highly saline, the lowest yields were consistently obtained.

4. As the sex ratio showed so little seasonal variation over the five-year period, selective trapping apparently is not feasible.

5. If the marsh owner could afford to delay trapping operations in this region until February 15, muskrats would have then reached their maximum development, in size and degree of primeness. Trapping success, however, is largely dependent upon prevailing water and weather conditions and full advantage must be taken of these. The latter have generally been such that an average of 53 per cent of the annual catch on the Blackwater Refuge has been taken during the month of January. Usually, low tidewater conditions during the latter part of the season have greatly hampered trapping operations.

SUMMARY

1. Approximately 5,233 acres of tidal marsh on the Blackwater National Wildlife Refuge in Maryland were trapped by Fish and Wildlife Service personnel from 1941–1945, with the closely controlled operations yielding 23,539 muskrats; 13,421 (57 per cent) were males and 10,090 (43 per cent) were females, a sex ratio of 133:100. This preponderance of males was consistently maintained throughout the entire trapping period each season and is regarded as significant.

2. In the race discussed, *Ondatra z. macrodon*, two distinct color phases occur. Of the total catch for the five-year period, 52 per cent were of the black-and-tan phase and 48 per cent brown.

3. Males were heavier than females, averaging 2 pounds 4 ounces (1,030 g.) and 2 pounds 2 ounces (962 g.) respectively, or a difference of 2.4 ounces (68 g.). Maximum individual weights

were: male—4 pounds (1,814 g.); and female—3 pounds 12 ounces (1,701 g.).

4. Carcasses consistently showed a rather small amount of fat, including those coming from luxuriant stands of *Scirpus olneyi*.

5. Average weights of the total catch varied little from year to year.

6. Weights increased progressively from January 1 to February 15, followed by a rapid decline.

7. Summarization of the catch into bi-weekly and monthly periods showed January to be the most productive month (53 per cent); January 16–31, the most productive bi-weekly period (27 per cent); and February 16–28, the least productive period with only 12 per cent of the average annual catch.

8. The best prime condition was generally reached during the last half of February but this period, unfortunately, yielded the smallest number of pelts.

9. A brief discussion of pertinent management principles is given.

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SPECIAL ARTICLE

AERIAL PHOTOGRAPHS, THEIR INTERPRETATION AND SUGGESTED USES IN WILDLIFE MANAGEMENT

Daniel L. Leedy

Ohio Cooperative Wildlife Research Unit,[1] Columbus, Ohio

Introduction

Although experiments in aerial photography date back to the last century, it was not until the first World War that any great advances were made in this field. Following World War I, the United States Coast and Geodetic Survey, the United States Geological Survey and other governmental agencies were quick to realize the possibilities of aerial photography in their work. Improvements were made steadily in film, cameras, airplanes, mapping instruments and techniques until the use of aerial photographs became standard procedure in many fields.

During World War II attention was again focused on the importance of aerial photography in military operations and many refinements were made in techniques. Colonel Paul C. Cullen (1946) stated that over 171,000,000 aerial photographic negatives were made for various military uses by the U. S. Army Air Forces during the second World War.

It was during the writer's experience as a photo interpreter in the intelligence detachments of the 8th and 9th Army Air Forces (1942–1945) that many of the ideas for this paper were formulated. This article was prepared to acquaint wildlife technicians with aerial photography and to suggest ways of obtaining photographs and of utilizing them more widely and efficiently in the field of wildlife management. The sources of photographs and equipment listed herein are not exhaustive. They are included only as a matter of convenience to the reader and are in no sense to be considered as advertisements for these companies or organizations.

Stegeman (1939) pointed out that three dimensional or stereoscopic pic-

[1] The Ohio Division of Conservation and Natural Resources, the Ohio State University, the United States Fish and Wildlife Service and the Wildlife Management Institute cooperating.

The writer wishes to express his thanks and appreciation to Dr. G. A. Swanson and Messers E. R. Kalmbach, F. C. Lincoln, W. L. McAtee and R. H. Smith of the Fish and Wildlife Service, Drs. C. A. Dambach, C. F. Walker and Mr. G. A. Petrides of the Ohio State University, Mr. R. N. Bach of the North Dakota Conservation Department, Mr. C. S. Spooner, Chief of the Relief Map Division, Army Map Service and Dr. W. E. Wrather of the U. S. Geological Survey for their helpful suggestions in the preparation of this paper; to Drs. L. E. Yeager and E. R. Kalmbach and Mr. G. P. Spinner of the Fish and Wildlife Service and Mr. W. N. Wandell of the Illinois Natural History Survey, who kindly read the manuscript and helped obtain aerial photographs as illustrative material; to Messers E. M. Elmore and Cecil S. Williams, Fish and Wildlife Service who also helped in securing photographs and Mr. James Dunavent, Columbus, Ohio, artist and former photo officer of the U. S. A.A.F., who gave helpful advice concerning types of aerial photographic equipment recommended for use in the field of wildlife conservation.

tures recorded a greater amount of information with greater accuracy than photos taken through a single lens and viewed singly. He urged wildlife technicians to secure stereoscopic cameras or stereoscopic attachments for their cameras and view the photographs with a stereoscope. He did not emphasize, however, the availability of aerial photographs or their importance in wildlife management work.

There have been relatively few published reports in wildlife literature citing the use of aerial photographs except as maps. In recent years, aerial photographs have been used in pictorial descriptions of study areas, Yeager (1941) and Hochbaum (1944) to cite only two instances; and as a basis for cover mapping as done by Dalke (1937), Crawford (1946), Marshall (1946) and others. Petrides (1944) pointed out the possibility of applying the principles of naval aircraft recognition to wildlife study by the split-second projection of aerial photographs showing deer, for example, as they would appear to observers in making an aerial census. Spinner (1946) suggested an improved segment method of estimating the numbers of birds seen in large flocks by the use of aerial photographs. He compared aerial photographs portraying known numbers of birds in flocks with large flocks of birds in the field.

The Bureau of Marine Fisheries of the California Division of Fish and Game made use of aircraft and aerial photographs in conducting a sea lion census in 1946 (Anonymous 1946). Wilcox (1940), Burwell (1942), Seely (1942), Wieslander and Wilson (1942), Spurr (1945) and others have described uses of aerial photography in forestry.

The use of aircraft in making aerial surveys of big game has been described by Bell (1937), Young (1938), Bennett, English and McCain (1940), Bach (1941 and 1945), Saugstad (1942), Rasmussen and Doman (1943), Olsen (1945), Hunter (1945), Aldous and Krefting (1946), Morse (1946) and Stuart (1947). Miller (1946) described the use of airplanes in censusing upland game in North Dakota under winter conditions. Fisher (1942) reported on the use of airplanes for censusing antelopes in Texas and driving or herding these animals in connection with trapping them.

An exhaustive bibliography on aviation and economic entomology has been prepared by Hawes and Eisenberg (1947). This bibliography includes 1,084 references to the use of aircraft in economic entomology work.

TYPES OF AERIAL PHOTOGRAPHS

The two main types of aerial photographs are the *oblique* and the *vertical*. Vertical photographs are those made when the axis of the camera is kept as nearly at right angles to the earth's surface as possible (Plate 4). Oblique photos are those made with the optical axis of the camera at an angle to the vertical. *High obliques* are made at a high angle to the vertical so as to show the horizon, while those made at a lower angle in which the horizon is not shown are known as *low obliques* (Plate 5). *Composite* aerial photographs are made with cameras having one principal lens and two or more surrounding and oblique lenses. The resulting photographs are rectified or transformed by means of a special projection printing machine so as to permit their assemblage as verticals with the same scale.

A *mosaic* consists of several overlapping vertical photographs joined together. *Uncontrolled mosaics* may be made simply by matching detail in the overlap or along the borders of prints. This type of mosaic gives a good pictorial effect of the ground, but may contain considerable errors in scale and direction. *Controlled mosaics* are obtained when several photographs are oriented by means of points along the line of flight and adjusted on previously selected ground points (Smith 1943). This type of mosaic is more accurate. When several photographs taken from a single airplane flight are joined by matching detail along the borders of each print, the result is a *strip mosaic*. Mosaics are used to provide a continuous view of areas too large to be covered by a single photograph. Continuous or uninterrupted *strip photographs* can now be taken by means of special cameras. *Photomap* is a general term used to denote reproduction of vertical aerial photographs, composites or aerial mosaics. As the term implies, photomaps are used primarily as maps.

Aerial photographs obtained from governmental and private agencies usually have data on their margins which aid in their use. Such information may include arrows indicating north and the direction of flight of the aircraft, locality, altitude of plane, focal length of camera, date and hour of exposure and serial number of the negative.

THE MAKING OF AERIAL PHOTOGRAPHS

The taking of aerial photographs and their development and printing have become specialities with which the user of photographs frequently has no direct connection. For a discussion of aerial cameras and the making of aerial photos, the reader is referred to Smith (1943) and other works cited by him. The Manual of Photogrammetry, 1944, Pittman Publishing Corporation, New York, is an excellent reference on aerial photography and is the official publication of the Society of Photogrammetry. Much information can be obtained also by writing to the manufacturers of aerial photographic equipment and to aerial survey companies.

It suffices to say here that aerial photography should be carefully planned, taking into consideration the time of day, season of the year, correct altitude for obtaining photos of the desired scale, and many other factors. For vertical photography, a plane with an opening in the floor of the cabin or cockpit is needed. Oblique photos can be taken by pointing a hand-held camera over the side of the plane or through a window, either open or closed.

Most vertical photographs are taken in sequence along the line of flight in such a manner that the individual photos overlap in area about 60 per cent. A pilot who takes pictures for mapping purposes usually flies in parallel strips close enough together that there is also a *sidelap* of about 30 per cent on the prints to ensure complete coverage.

PRESENT STATUS OF AERIAL PHOTOGRAPHY IN THE UNITED STATES

Most of the continental area of the United States has now been photographed from the air. A large part of

the photography has been accomplished since the middle thirties by the United States Department of Agriculture, the Geological Survey, the Coast and Geodetic Survey, the Tennessee Valley Authority and the Army Air Corps.

Marshall S. Wright (1946) stated that from 1926 to June 30, 1945, the U. S. Department of Agriculture contracted for or executed directly, 2,945,000 square miles of vertical photography at a cost of $9,014,000 or $3.06 per square mile. This photography, for the most part, was of a scale of 1:20,000 and covered nearly all of the agricultural land of the United States. A map showing the extent of aerial photography by the Department of Agriculture as of March 31, 1946, is available from the Office of Plant and Operations, Washington 25, D. C.

W. E. Wrather, Director of the U. S. Geological Survey, stated (*in litt.* May 17, 1946) that about 85 per cent of the land area of the United States is covered by aerial photography of Federal Agencies. Although most of this photography was restricted for public use during the war, it is now being released for purchase and usually can be obtained in the form of contact prints, general enlargements, ratioed enlargements and copy negatives.

SELECTING PHOTOGRAPHS FOR USE IN WILDLIFE MANAGEMENT

With aerial photographs available for most of the United States, it would seem desirable that they be used more frequently and effectively in the field of wildlife management than at present. Choosing the correct type of photography becomes an important consideration in ordering photographs already available or in contracting for additional aerial photography of any given area.

For mapping purposes, vertical photographs are the most desirable type. They show an area somewhat as it would appear on a detailed map of similar scale and provide the most complete picture possible. The area covered by vertical photos is rectangular in shape and the scale is fairly uniform. Vertical photos with a 60 per cent overlap also permit the use of a stereoscope for detailed study.

Oblique photos are effective for illustrative purposes in that they provide a sweeping view in a more familiar perspective. The high oblique covers a larger ground area than any other type of single photo. Unlike vertical photos, however, with scales fairly uniform on any given print, the scale of an oblique decreases in geometric progression from foreground to background. Ground features may appear considerably distorted on obliques. For example, slopes facing toward the camera are enlarged and those facing away from the camera are reduced in area.

The comparative value to wildlife managers of the different types of photos depends on the purposes for which they are to be used. Oblique photos have advantages for pictorial purposes such as illustrating a certain cover type, portraying the landscape features of a study area or showing details of steep slopes. Verticals are best for making measurements and for detailed mapping. Often, the two types can be used together to advantage. A scale of 1:8,000 or less enables the photo interpreter to obtain much more detailed information about cover types

and other features than smaller scale photography of 1:20,000 or more.

The Soil Conservation Service has found that for a comprehensive determination of various factors such as slope and erosion classes, soil types and land-use capabilities, photos on a scale of less than four inches to the mile (1:15,840) are too small (Wright *op. cit.*). Wright also reported that a scale of 1:15,840 was suitable for a variety of uses in forest type mapping. The printing paper should be of good weight, fine-grained and with semi-matte or glossy finish so that magnifying stereoscopes can be used in examining the photographs.

Aerial photographs in color, although expensive, are well adapted for showing the extent of serious damage to forests caused by insects, diseases, or fires and for other special illustrative purposes.

How and Where to Obtain Aerial Photographs

After the proper type of aerial photography has been selected, the next step is to ascertain the agency having the negatives that cover a designated area. This information usually can be obtained at the County, State or Regional Offices of the Department of Agriculture or by writing to the Map Information Office, Geological Survey, Department of the Interior, Washington, D. C.

If possible, the serial numbers of the photos covering the desired area should be obtained before placing an order for photographs. Index maps of Agriculture Department photography from which these numbers can be obtained are usually available at the state and local offices of the Department of Agriculture. Photo index sheets may be obtained also at 60 cents per sheet from the Map Information Office at Washington, D. C.

It should be remembered that if only small scale photographs of a given area are available, enlargements usually can be obtained which will give the desired amount of detail.

Orders for reproductions from the proper negatives should be sent to the agencies holding the negatives. In the case of the U. S. Department of Agriculture, orders should be mailed to the Office of Plant and Operations, U. S. Department of Agriculture, Washington 25, D. C.

Orders for U. S. Geological Survey photography should be sent to The Director, Geological Survey, Department of the Interior, Washington 25, D. C.

According to W. E. Wrather (*in litt.* 1946), aerial photographs from either the Geological Survey or the Department of Agriculture can be purchased at the following prices: "prints, 1–5, 65 cents each; 6–100, 40 cents each; over 100, 35 cents each; county coverage, 30 cents each." These prices are, of course, subject to change.

The Department of Commerce, the War Department and the Navy Department also have some aerial photographic coverage of the United States. Inquiry concerning its availability and cost as well as scale, flying height and other data can be obtained from the respective departments.

If recent photography of the desired type is not available, it may be feasible to make a contract with a commercial firm to take and develop the photographs. For state conservation departments and other agencies requir-

ing considerable aerial photography, it might be practical to purchase some of the outdated but none-the-less usable photographic equipment available as surplus war goods, and to take their own pictures. In many localities, men with considerable wartime experience in aerial photography would welcome an opportunity to do photographic work on a part time or full time basis.

For wildlife agencies contemplating the purchase of surplus equipment, it is suggested that the Fairchild Models K-17-C and K-20 would satisfy most of the requirements. The K-17-C may be operated manually or by a 24-volt power unit in the plane and can be used for both large and small scale vertical photographs. It has a 12 inch focal length and takes 9″×9″ photographs. For all-around use, the following accessories are recommended:

(1) Extra A-5-A magazines
(2) A-8 ring mount for taking verticals
(3) A-2 viewfinder for verticals
(4) B-2 or B-3 intervalometer with cables
(5) Filter set including Wratten K-2, Aero 2, G, 23-A
(6) B-1 Cut film back for Kodachromes

The K-20 is a smaller camera which can be held in the hands and used to good advantage in taking obliques. It has a $6\frac{3}{8}$ inch focal length which enables the operator to take large scale photographs of subjects impossible to get with the larger types of cameras. The Speed Graphic camera with 4″×5″ film pack gave good results in big game aerial census work in Minnesota according to M. A. Morse (*in litt.* May 6, 1946).

Another possibility is that of obtaining aerial photographs from various units and squadrons of the U. S. Army and Navy throughout the country. These squadrons frequently make trial flights for training purposes and for improving their aerial reconnaissance techniques. They willingly cooperate with federal and state agencies, making available excellent quality photographs at little or no cost.

METHODS OF STUDYING AND INTERPRETING AERIAL PHOTOGRAPHS

A great deal can be learned from a detailed study of aerial photographs that escapes the attention of the casual observer. To get the most out of a photograph, it is necessary to have an accurate determination of the scale, have the photograph correctly oriented, have a knowledge of the field in question and exercise sound reasoning.

In examining a photograph, shadows cast by objects on the print should normally fall toward the observer. If

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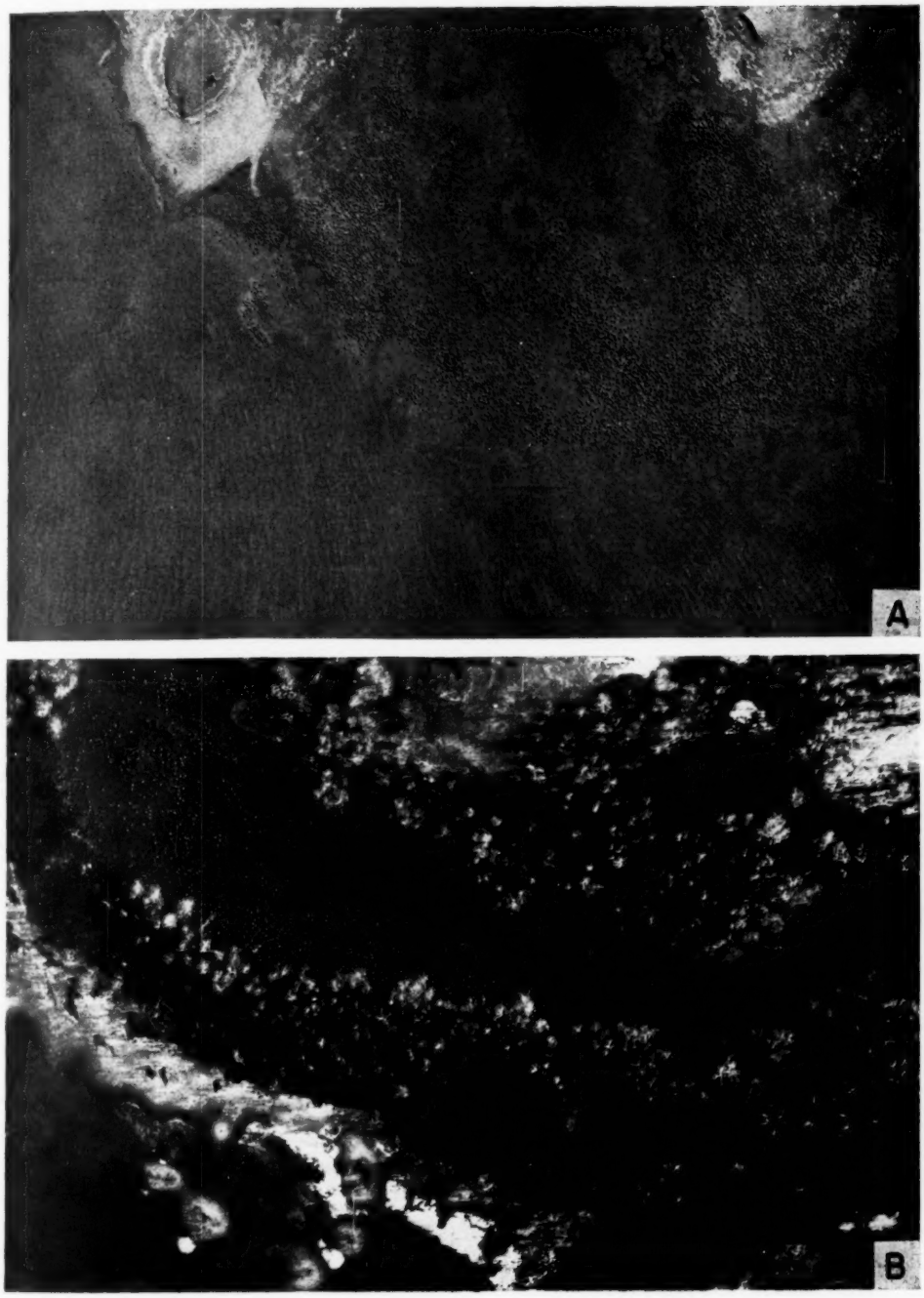
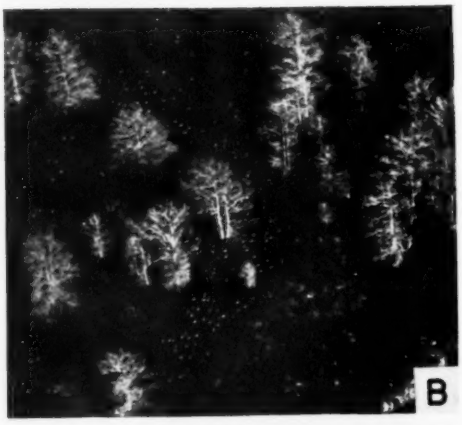
EXPLANATION OF PLATE 4

A. A section of a vertical photograph showing ducks (pintails and widgeons) at Laguna Madre, Texas, January 27, 1947. Viewed by means of a reading glass if used singly or through a stereoscope if used in stereo-pairs such photos are of much value for waterfowl censusing. Photo by Chief Petty Officers J. W. Temple and S. Peters using a K-17 camera in a Navy PBY. Scale, approximately 1:1,000.

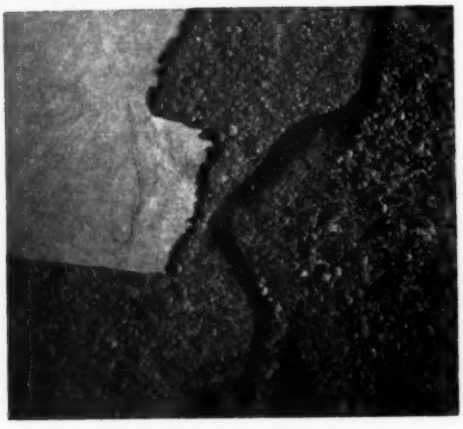
B. Section of a vertical photograph showing ducks at Barr Lake, Colorado, January 13, 1947. The use of a stereoscope on such photos will enable the technician to obtain more accurate counts than by viewing single photographs or by attempting aerial counts alone. Photo by courtesy of Army Air Forces, Lowry Field, Colorado. Scale, approximately 1:900.

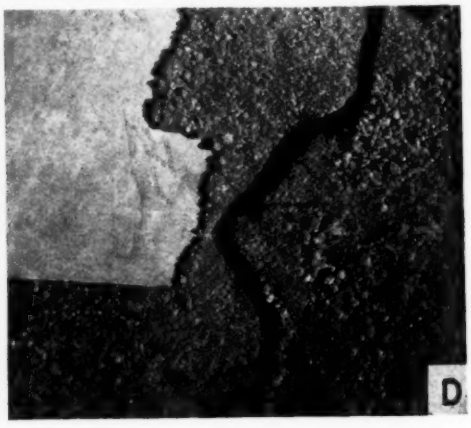

A
B

A


B

C




D

the photograph is not correctly oriented with respect to the light used for reading it, the relief may seem reversed with valleys appearing as ridges and vice versa.

In reading single prints or mosaics, the photo interpreter relies chiefly upon form, pattern, color tone and shadows in recognizing natural and man-made features. Magnification of from 2 to 4 diameters brings out many details on single photos and often helps one to visualize relief. Examination of paired photos which overlap in area can be made with the aid of a stereoscope. It is only through the use of a stereoscope that the full potentialities of aerial photographs can be realized.

Stereoscopes are of two main types, the refraction, or lens type, and the reflection, or mirror type. The refraction is the more simple and compact, consisting of 2 matched lenses separated by a distance corresponding to that between the eyes and mounted on a suitable support. The lenses usually have a magnification of from 1.25 to 4 diameters. A magnification of about 2.5 is good for average work.

The reflection type of stereoscope consists of four mirrors set at angles of 45° to the plane of the photos. This type of stereoscope costs more and is less compact than the simple refraction type. The refraction type, due to the magnification of the lenses, also has the advantage of providing a more detailed view with a heightened relief effect. All things considered, it is probably the most useful type for wildlife managers. At the time of writing, simple refraction types of stereoscopes could be obtained from optical companies at a cost af about $10.00 each.

For detailed instructions in using a stereoscope, it is suggested that the readers who have had no experience in photo interpretation refer to texts such as those cited previously or contact someone who is familiar with the procedure, perhaps in Soil Conservation Service or Production and Marketing

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EXPLANATION OF PLATE 5

A. High oblique of the Rock River, Illinois deer habitat, Ogle County, February 10, 1947. Note the deer in the foreground and the horizon in the background. Photo, courtesy Willet N. Wandell, Illinois Natural History Survey. Camera used: Fairchild K-20.

B. Low oblique showing waterfowl on Horseshoe Lake, Alexander County, Illinois, January, 1947. Obliques taken at low altitudes complemented by large scale vertical photos make possible fairly accurate counts of ducks even in sparsely wooded areas such as this. Photo, courtesy Cecil S. Williams, Fish and Wildlife Service. A K-20 aerial camera with 4″×5″ negatives was used for making this photo, only a section of which is reproduced here.

C. Section of low oblique showing ease with which deer can be counted under these conditions of scattered deciduous trees and snowy background. Photo, courtesy Willet N. Wandell, Illinois Natural History Survey. As indicated by Willet N. Wandell the encircled deer at the left of this enlargement is evidently a buck that retained his antlers up until the time of photography, February, 1947.

D. A stereo pair of photographs taken at an altitude of 5,000 feet. Note the livestock grazing in the pasture and the stream winding through the forested area. Bombay Hook Refuge. 5*D* to 6*B*, courtesy Colonel Donald B. Diehl and Master Sergeant Robert Livingston, 4146 Base Unit, AMC; USAAF.

Agency offices. Essentially, all that is required, however, is to place two photos in correct overlapping relation to one another, set the stereoscope directly over two complementary image points on the photo approximately 2.5 inches apart and stare at these points (a crossroads for example) until stereoscopic fusion is obtained. Only a very little practice will be necessary before most people with normal vision can readily get true depth perception. Wildlife managers and others who use aerial photographs will find their efforts well justified in obtaining a stereoscope and in learning to use it.

In beginning a study of aerial photographs, it is desirable to know the scale, the location, the date, the correct compass orientation, the focal length of the camera used and the time of day when the exposure was made. As indicated earlier, some of this information is usually on the margin of the photographs. If not given, the scale may be calculated (1) from the altitude at which exposure was made and the focal length of the camera, (2) by determining the ratio of distances between selected points on a map of known scale and the same points on the photo, and (3) by ground measurements of distances between points that can be identified on the photo. Scale is usually given in terms of a simple fraction as 1/8,000. It expresses the relation of photo distance to ground distance in like units of measurement. The scale may also be converted into other terms such as miles or feet per inch. To calculate the scale (representative fraction) by focal length and altitude, the following formula may be used:

$$RF = \frac{\text{Focal length in feet}}{\text{Height of airplane in feet}}.$$

Thus, if an exposure is made at an altitude of 20,000 feet with a camera having a focal length of 12″ (1 foot), the scale of the resulting photograph would be 1:20,000. If the camera had a focal length of 6″ (.5 foot), the scale would be 1:40,000 or if the focal length were 24″ (2 feet), the scale would be 1:10,000.

If the altitude given is the elevation above sea level, and if the average ground level is much above sea level, allowance must be made by reducing the altitude used in the formula the necessary amount, *i.e.*, the elevation of the ground above sea level.

In computing the scale by comparison of two points on a photograph with points on a map of known scale or by comparison with ground distance, it is well to select two points near opposite corners of the photo so that a line joining the points will pass close to the center of the picture. Then, assuming that the distance between the two points is 3 inches on a map of 1:50,000 and the distance between these points on a photograph is 6 inches, it is apparent that the scale of the photograph is just half that of the map or 1:25,000.

Orientation of the photos may be accomplished by comparing them with maps or by orienting them with some recognizable feature on the ground such as a road. A third method is by the use of shadows which, in most of the Northern Hemisphere, fall towards the northwest, north or northeast in the morning, at noon or in the afternoon respectively.

The identification of features on photographs requires a certain amount

of practice and it is well if the interpreter can actually compare the photographs with features on the ground. By so doing, he can soon learn to recognize natural and man-made features represented on the photographs. He can also learn the limitations of any type and scale of photography for a given purpose.

The shape of an object, and the shadow, it casts, are very important aids in identification. Lombardy poplars, for example, can be identified by these means and differentiated from more branching and sprawling types of trees.

The apparent size of objects or their relation to associated features is also important in photo interpretation. Objects too small to be readily identified on photos may be distinguished by studying their relation to surrounding known features.

Pattern is often helpful. Orchards or plantations of trees, for example, can be distinguished from natural forest land by the regular spacing of trees. Various types of land-use and field patterns are also easily recognized. Streams may be identified according to the meandering or dendritic patterns and the vegetation commonly growing along them (Plates 5 and 6).

The third dimension or stereoscopic relief revealed under the stereoscope is of great importance in most phases of photo interpretation. The use of a magnifying stereoscope brings out many details of topography, drainage, vegetation types and other features otherwise impossible to recognize.

Smith (*op. cit.*) designates the texture of photographs by various descriptive terms as coarse or fine, smooth or rough, even or uneven, granular, matted, wooly etc. Grassland shows an even to mottled texture, bare sand and quiet water have a smooth, even texture, forested land is usually characterized by a rough texture.

The color tone of aerial photographs varies considerably with the type of film and filter used, the nature of the topography or features photographed, the angle at which the photos were taken, the manner in which light is reflected from the objects photographed and other factors. The color tone of plowed fields is generally grayish and may vary from almost white in dry, sandy areas to dark gray in areas of muck. Vegetated areas of forest or grassland usually show a dark color tone.

The stereo pairs shown in Plates 5 and 6 indicate the manner in which size, relation to associated features, pattern, texture, stereoscopic relief and color tone are helpful in the recognition of ground features represented on aerial photographs.

The methods for determining the heights of objects represented on aerial photographs are described by Smith (*op cit.* pp. 10 and 89). Seely (1942) and Spurr and Brown (1946b) have described how to determine tree heights by various methods. The latter investigators stated that forest stands could be classified accurately into 10-foot height classes at a photographic scale of 1:16,000 and into 5-foot classes at a scale of 1:12,000. The parallax ladder as used by the Photographic Intelligence Center, Navy Yard, Washington 25, D. C., is said to be a simple inexpensive device for the determination of elevations from aerial photographs even

without the use of a stereoscope.

Several factors affect the accuracy with which heights may be obtained—slope of the ground, tilt of the airplane, density of foliage in the case of trees, and the angle of photography. To obtain heights by the use of shadows, it is necessary to know the time and date of exposure, the latitude of the object photographed and the length of the shadow. Height values based on the length of shadows are accurate only when the shadow is cast on flat ground and the base of the object which casts the shadow is visible beneath the point or edge where the shadow begins.

With some practice, it is possible to judge relative heights fairly well by simply noting the length of shadows cast and comparing them with known features of the landscape.

SUGGESTED USES OF AERIAL PHOTOGRAPHS IN WILDLIFE MANAGEMENT

The following uses for aerial photographs in the field of wildlife management are suggested with the hope that they may be tested and that they may result in the further application of aerial photography in wildlife research and management.

MAPS

Two important and widespread uses of aerial photographs are as maps and as aids in map making. They may be used as guide maps because they show roads, tracks, ridges and streams in their proper relation and are of much value in the original inspection or survey of a wildlife management area.

They may also be used as base maps for recording various kinds of data including land-use, soil types, vegetation types, refuge areas, property lines and other features. Aerial photographs used singly or in mosaics may thus serve as a base for making contour maps, cover maps, soil maps and land-use maps. They are useful for determining the size of areas and planning land-use readjustments.

Photographs to be used as guide or base maps preferably should be mounted on some sort of base cloth such as Chartex to prevent tearing and cracking. Chartex is manufactured by Seal, Incorporated, Shelton, Connecticut. It is obtainable in cut or roll form and is easily applied.

Cover maps can be made most accurately from large scale, vertical photographs of good quality. The photo interpreter or technician making the cover maps should be familiar with the area and determine the accuracy of his interpretation with frequent ground studies of the vegetation. Wieslander and Wilson (1942) described a system used in classifying forest and other vegetation types in the Forest Survey of California and Western Nevada.

Spurr and Brown (1946a) in discussing the specifications for aerial photographs used in forest management pointed out that the best resolution of detail was obtained with Kodak Type B infra-red film using a minus blue No. 12 filter. With such film they found that red pine, red spruce and Scotch pine appear very dark on photographs; white pine, white spruce and Norway spruce have a gray tone; hemlock European larch and tamarack have a light gray tone and hardwoods such as red maple, sugar maple, red oak, white oak and paper birch appear on the photographs in a very light tone. These

same observers indicated that photographs of a 1:15,840 (four inches to the mile) scale were almost universally applicable for forestry work, but recommended a 1:9,600 scale for intensive management and for volume estimating.

The making of contour maps from aerial photographs is treated in considerable detail by Smith (*op. cit.* pp. 192–216). A planimetric system of mapping, used by the Soil Conservation Service, is described by Cude (1940).

Complex instruments may now be obtained from Bausch and Lomb, The Aero Service Corporation, the Fairchild Camera and Instrument Corporation, the Abrams Instrument Corporation and others which are excellent for the transferring of information from an aerial photograph to a mapping base, and at the same time making change in scale and correction for tilt. These instruments are fairly expensive and require some skill in operating them, but would be desirable for large scale mapping projects.

EVALUATION AND DETERMINATION OF GAME RANGE

Aerial surveys of game range are the most practical approach to the study and management of wildlife tracts in wilderness areas and extensive marshlands inaccessible to automobiles and other means of transportation. Even in more accessible areas, aerial surveys may be more economical than the slower and more tedious ground surveys. Much can be learned by direct observation from low flying planes, but aerial photographs, taken of the wildlife areas flown over, add much to the value and utility of such aerial surveys. Detailed stereoscopic study of aerial photographs should enable a game technician to learn much about habitat conditions at the time of the survey and the photographs provide a permanent record for comparisons and future uses.

For example, aerial photographs used in conjunction with ground studies would enable a game technician to outline with considerable facility and accuracy the potential deer range in a given locality (Plate 7). Wooded or brushy areas are readily discernible on mosaics made of small scale photographs representing relatively large areas.

In extensive nesting areas of waterfowl, seasonal variations in the flooded and unflooded sections could be mapped with a minimum of time and effort using aerial photographs. If the success of nesting on representative sample areas were determined by ground studies, estimates could then be made for the waterfowl produced on much larger areas. Relatively small scale photographs each covering a large expanse of marsh would be suitable for such mapping and cost much less than large scale photography. If it became desirable to study some particular part of the marsh area in detail, enlargements could be made from the negatives covering that part.

In conducting studies of ground nesting birds such as the pheasant, it has been learned that in certain years many nests are destroyed by flooding. The extent of such flooding could be readily shown by photographs taken at the peak of a flood. The losses in pheasant production due to nest destruction would obviously have to be determined by intensive nesting studies made on

the ground on sample areas. In flat regions, as in much of the pheasant belt of northwestern Ohio, a difference in elevation of only a few inches may mean the difference between flooding or not flooding after periods of heavy precipitation. Such slight differences in elevation are not readily apparent to a man on the ground, but should be considered in a pheasant management program which has as one of its chief aims the establishment of undisturbed nesting cover strips. By referring to photographs or mosaics of an area in flooded condition, the establishment of nesting cover, in localities likely to be flooded, could be avoided.

As an Aid in Censusing Animals

Although aerial surveys of big game were made as early as 1931 in Utah by Orange Olsen (*op. cit.*) and are now being employed in many states, there has been very little use of aerial photography in conjunction with the direct counts of game animals made by the aerial observers.

In Minnesota, some aerial photographs were taken during their aerial survey of big game, but they were not used to check the accuracy of the game tallied from the air (Morse *in litt.*, June 6, 1946). It is the considered opinion of the writer that the use of aerial photographs as a check would be a worthwhile addition to the aerial census method and Morse indicated that he expected to use this approach in the future. Willet Wandell (*in litt.*, April 24, 1947) reported on the aerial census of deer on the Rock River, Illinois, area and stated that aerial photos of one herd revealed 109 animals rather than the 105 observed from the air. Photographs of other deer herds censused might have shown greater differences obtained by the two methods. Donald D. McLean (*in litt.*, April 10, 1947) stated that a K-20 aerial camera had been used to photograph antelopes and Rocky Mountain mule deer in California as a part of their recent aerial survey of big game.

Morse (*op. cit.*) pointed out that for counting moose and deer, the optimum altitude for flying was about 500 feet. At this height, two observers could view a strip $\frac{1}{8}$ to $\frac{3}{16}$ mile wide for big game. A light plane seating three people and flying at a speed of 60 to 80 miles per hour was considered suitable for aerial surveys of this type. Morse also reported that in Minnesota, the cost of their aerial censuses to date had been $1.09 per square mile in comparison to the $220.00 per square mile cost of census by the deer drive. A deer drive required approximately 160 man days of labor for the census of one square mile. On five aerial censuses made in Minnesota, only 62 man days of labor were expended to census 746 square miles. These differences represented tremendous savings to the state.

Large scale photographs taken along the flight line of the aircraft and examined carefully under a stereoscope would make possible more accurate counts of big game than visual observations alone. The photographs would also form a permanent record of the condition of the range at the time of photography and show what part of the range was occupied.

Continuous strip photography would appear to offer possibilities for aerial census work. As reported by Kistler (1946) the Sonne stereoscopic strip

camera was an important advance made in World War II. This camera makes possible low altitude, large scale (up to 1:300) photography at high plane speeds. The film is moved continuously past a slit in the focal plane of the camera and is synchronized to the movement of the ground image as the airplane passes over the terrain. As the airplane moves in flight, the film continuously records the terrain passing below on an uninterrupted strip photograph. Stereoscopic photos are obtained by partitioning the lens cone and using two lenses. The strip photographs can be viewed stereoscopically on the continuous roll by means of a special mirror type of stereoscopic viewer. The writer has seen this type of photography demonstrated with splendid results, but knows very little about the type of equipment required, the costs and other details. These details could be obtained from the Chicago Aerial Survey Company and other commercial companies.

The type and density of cover, weather conditions, topography and season of the year should all be considered before attempting an aerial census of big game. Favorable conditions for the aerial censusing of deer include a range of deciduous forest species from which the leaves have fallen, a snowy background, good flying weather and a topography not too rough in character. The banding and movements of big game animals should also be considered. For example, in North Dakota Bach (*op. cit.*) and Stuart (*op. cit.*) found that a census in late August and early September provided a more representative picture of the resident antelope population than an early summer census, before any fall banding had occurred, or a winter census, when most of the animals had migrated out of the state. Usually, antelopes and buffalos would be visible on photographs even without a snowy background. Rasmussen and Doman (*op. cit.*) found that mule deer in Utah and other western states were difficult to census by airplanes due to the rough mountain ranges and the fact that the deer's main winter range in that region was of the pinon-juniper type. Deer could not be seen in aerial photos of dense coniferous cover even in the winter. They would appear, however, on photos of valleys or slopes with deciduous cover even though they could not be seen readily by observers in a plane traveling 90 to 100 miles per hour. Due to the location and type of habitat in which caribou are found, the aerial census of these animals would appear to be a feasible method of determining their numbers.

Muskrat houses in marsh areas are recognizable on aerial photographs and can be counted much more readily and completely than by attempting to record them from a boat or from the borders of a large marsh (Plate 6, *A*). If the numbers of muskrats represented per house could be satisfactorily determined by ground studies preceding an aerial survey, the number of houses multiplied by an accurate conversion factor would indicate the number of muskrats on a given area.

The number of muskrat houses appearing per unit of area on a photograph taken in the fall might also be used as an aid in determining the number of muskrats that could be removed safely during the trapping season. As the number of muskrats represented by

a muskrat house varies from year to year and according to the season of the year, any estimates on muskrat populations determined by a count of the houses must be based on careful ground studies preceding the aerial photography. Vertical photographs of a scale of 1:4,000 up to 1:10,000 are suitable for muskrat house counts.

David B. Vesall summarized his experiences in the aerial census of muskrats in Minnesota at the Midwest Wildlife Conference held at Columbia, Missouri, December 5–7, 1946. He stated that in three days of flying, totalling fifteen hours and twenty minutes flight time, a four-man crew censused a strip of muskrat marsh 1,487 miles long by one and one-half miles wide at a total cost of $335. Some photographs taken concurrently with the aerial survey would have provided permanent records of considerable value in a research or management program and would have served as a check on the accuracy of the counts made by the observers as they flew over the marsh.

The U. S. Fish and Wildlife Service and the Illinois Natural History Survey have employed airplanes in their studies of waterfowl for several years. Aircraft are now being used as a means of estimating numbers of waterfowl especially during the winter. Large scale photographs taken during the aerial surveys of waterfowl would serve as a valuable check on the counts made by observers in a plane. The excellent aerial photographs exhibited by Dr. E. R. Kalmbach and Mr. E. M. Elmore at the North American Wildlife Conference in 1947 show that accurate counts can be made of enormous rafts or flocks of ducks. On small scale photographs in which individual ducks cannot be counted, the area represented on the photographs as well as the percentage of the total area occupied by rafts of waterfowl could be calculated easily and multiplied by a conversion factor to indicate the total number of waterfowl present. The conversion factor *i.e.*, the number of ducks actually present on selected areas, could be obtained (1) by ground counts, (2) by enlarging some of the small scale photographs so that individual ducks can be counted or (3) by direct observation from a low-flying plane. Mississippi Flyway Biologist, Robert H. Smith (*in litt.*, Sep-

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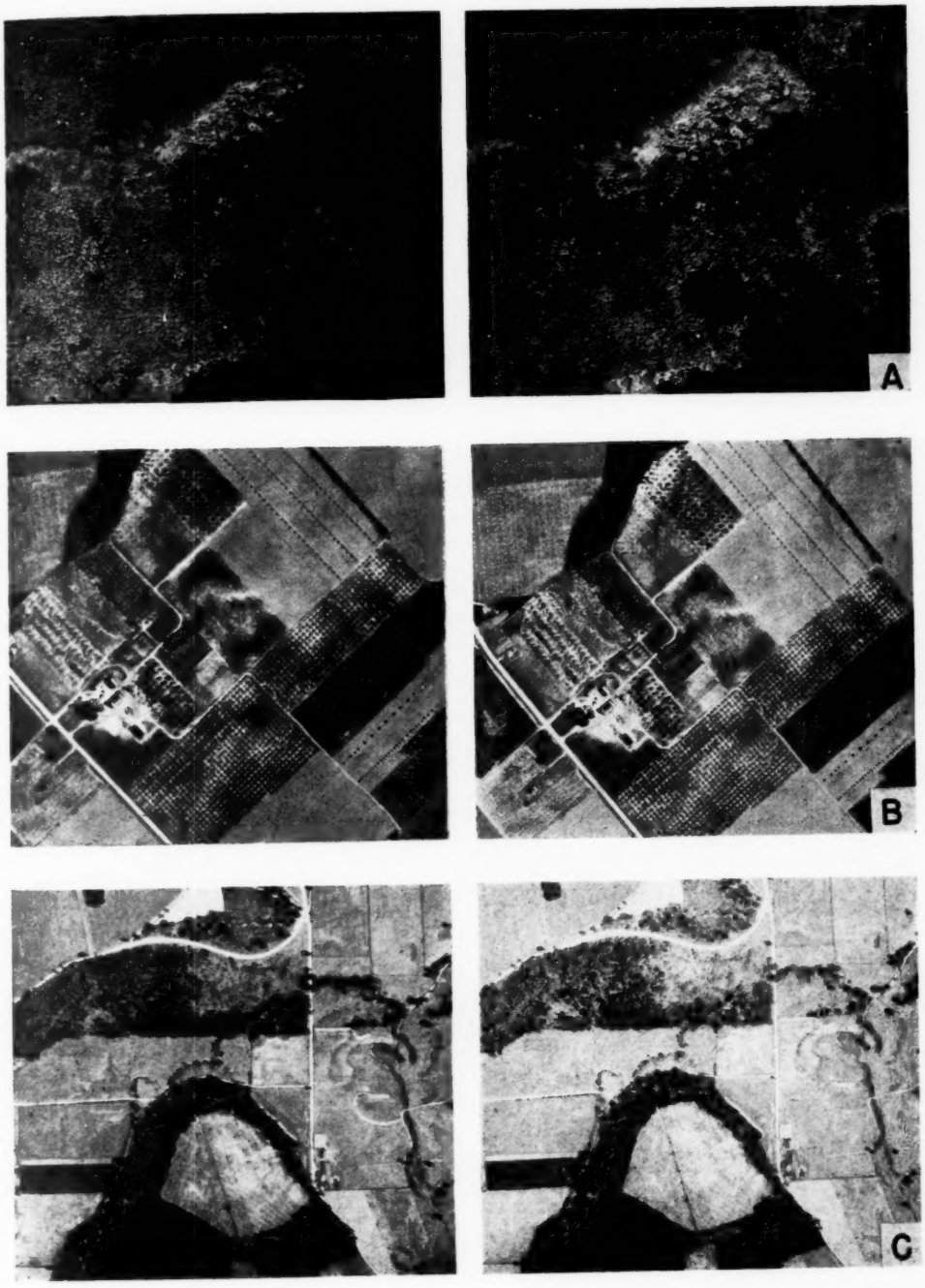
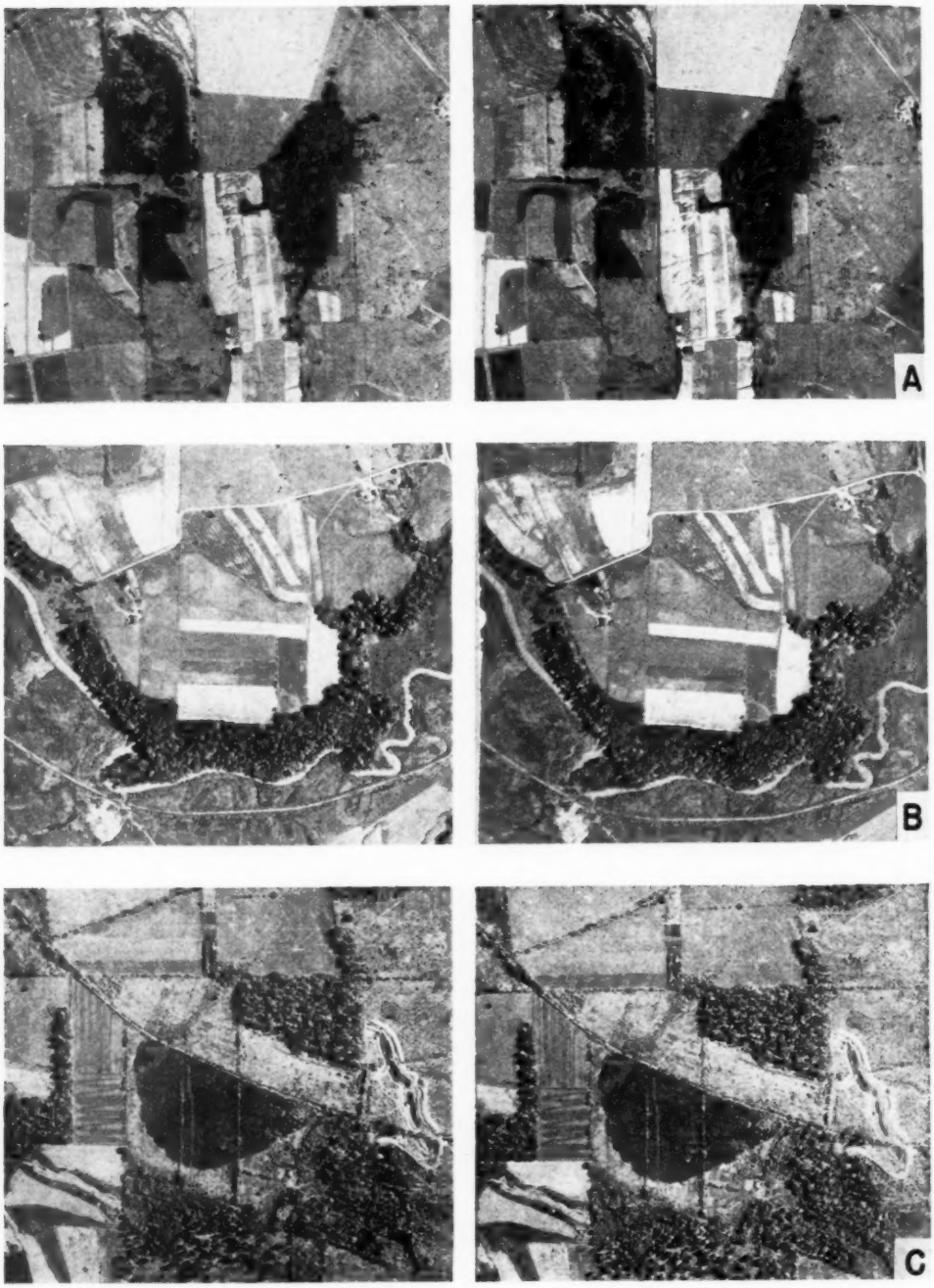
EXPLANATION OF PLATE 6

A. Sections of vertical photographs taken October 9, 1945, showing muskrat houses on the Blackwater Refuge, Delaware. The water area appears dark and the muskrat houses light in contrast to the marsh vegetation. At a scale of 1:5,000 a 9×9-inch print represents approximately 322 acres of marsh land and furnishes an accurate, cheap means of determining the number of muskrat houses on large, relatively inaccessible marsh lands.

B. Note the regularity of the orchards, plantations and truck gardens as contrasted to the native wooded tract on the Bombay Hook Refuge, Smyrna, Delaware. Note also the shocked corn and other agricultural crops; the woody as contrasted to the clean field borders and the mottled dark and white effect of the various soil types indicating differences in natural drainage.

C. A steep-sloped valley in eastern Ohio. Note the hilly topography shown by these and the following USAAF photos taken in Tuscarawas County, Ohio, September and October, 1942, at a scale of approximately 1:18,000. Much of the land here is devoted to pasture.


A
B
C


A
B
C

tember 27, 1946), reported that "waterfowl are easily identified from aircraft moving at ground speeds up to 130 miles per hour and at elevations not to exceed 200 feet." Smith pointed out further that often after a raft of ducks has been photographed, it would be much cheaper to make a low flight over the raft to estimate the percentage composition of species than to make a special trip by ground or water for this purpose because the rafts are sometimes inaccessible.

The chief advantages of flying at relatively high elevations in photographing rafts of ducks are (1) the small scale photographs cover larger areas and are relatively cheap and (2) the ducks are not frightened by the airplane.

Observations from the air in conjunction with aerial photographs would appear to be the most practical method for censusing large rafts of ducks on open water in relatively inaccessible areas. It would be impractical, of course, for economic reasons, to photograph the entire range over which wintering waterfowl are dispersed. Stereoscopic examinations of photographs should be made in counting ducks which might be partially hidden by trees or other vegetation along river banks or in swamps (Plates 4, *A-B*, and 5, *B*).

Mr. George P. Spinner (unpublished ms, 1946) was able to count individually all of the geese in an aerial photograph of the Greater Snow Geese. These geese, which were resting in the Bombay Hook National Refuge, were chased out over the bay to provide a dark background for the photograph; being white, the birds showed up exceptionally well.

Miller (*op. cit.*) reported on the use of the airplane in censusing upland game birds in North Dakota. He found that, due to heavy snows, pheasants and other upland game could be counted easily from a plane flying at an altitude of 100 to 300 feet whether they were in patches of sweet clover, weeds or other cover. Large scale photographs might be of some value in counting particularly large groups of such game birds in winter concentration areas, but would be impracticable for many areas with sparse populations.

Such animals as seals grouped together on ice appear quite plainly in aerial photographs as illustrated by Bartlett (1929: 13) in an article en-

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EXPLANATION OF PLATE 7

A. Severe gully erosion appears on the slope shown near the center of these aerial photographs. Contrast the land use here with that illustrated in photo 6B. Note the extensive pasture to the right which is reverting to forest and providing more deer territory in eastern Ohio.

B. Note the wooded slope which, here, is about 40 feet in height, the strip-cropping now being practiced to combat soil erosion losses, the gentle curve of the abandoned railway which follows the valley and the sharp curves in the secondary highway on the upland. The lighter toned trees are assuming their autumn colors.

C. More deer and grouse country in the making here. The dark area near the center of the photographs results from a grass fire; the dark streaks in the field to the left indicate that manure was spread here for pasture improvement. To the right and lower left are strip-mined areas with considerable wildlife management potentialities.

titled "The Sealing Saga of Newfoundland." The possibility of obtaining seal censuses by the aerial survey method thus seems obvious. As indicated earlier (Anonymous, *op. cit.*) the Bureau of Marine Fisheries used aircraft and aerial photographs to aid them in the 1946 sea lion census in California. Observers found that they could make counts and estimates of sea lions from airplanes or blimps and that aerial photographs were very useful as a check of such counts. The aerial survey method had a great advantage over counts made from boats in that flights by air permitted coverage of all the state waters in two or three days. Thus complete counts could be made before the sea lions had time to move from rookery to rookery, thereby introducing an error in a survey of similar coverage from boats which would have required two or more weeks to complete.

As an Aid in Locating Game Refuge Sites

Aerial photographs can be of considerable use in selecting potential sites for waterfowl and upland game refuges. Pheasant refuges in Ohio for example, have been found to be most successful when located according to a more or less general pattern with a refuge near the center and others near each of the four corners of a county. By examining aerial photos which already are available, it is possible to select certain areas in strategic localities as potential refuge sites. The location of these potential sites can then be transposed to a county highway map and visited by driving to them directly, thus saving considerable time and mileage. In northwestern Ohio, the most suitable winter cover for pheasant refuges consists of brushy thickets which can be recognized as such on the 1:8,000 scale photographs available. The type of land-use which is of major importance in selecting pheasant refuges can also be determined from aerial photographs.

Some of the potential refuge areas selected from aerial photos would undoubtedly prove to be lacking certain desirable features when examined more closely on the ground, but most of the physical features such as topography, land-use and cover could be determined by using aerial photographs.

In like manner, some of the localities spotted in remote areas by aerial observers as being used for natural resting sites by migrating waterfowl could be photographed, the aerial photographs later serving as an aid in selecting and establishing waterfowl refuges. Since the photographs would indicate the extent to which a given area was used and the parts of the area most occupied by waterfowl, they would be helpful not only in determining good refuge sites, but also in determining appropriate boundaries for these refuges.

As an Aid in Law Enforcement

Various types of aircraft have been used in recent years as an aid in law enforcement work. In some situations, aerial photographs could be used as evidence of game law violations. For example, commercial fisherman may be allowed to fish only in certain parts of a large lake, the illegal or restricted waters being marked by means of buoys. Since these markers or buoys might not be visible from shore and since fishermen might readily move their boats

from restricted to legal fishing areas at the approach of a patrol boat, it would be difficult to enforce the regulations prohibiting fishing beyond a certain line. Now if a fishing boat were seen in the restricted waters by observers in an airplane and if the boat were photographed from the air in such a way that its location could be accurately plotted in relation to the legal fishing area, the photograph could be used as indisputable evidence in court.

As an Aid in Mapping and Studying Areas Damaged by Fire, Floods, Insects or Disease

Aerial photographs show very clearly the freshly burned areas in grasslands and wooded areas (Plate 7, *C*). Determining the extent of grassland burns, which appear dark on photographs, might be of considerable value in estimating losses to game as a result of fire. The blackened stubs of trees found in old burned-over forest areas are easily recognized on photographs as are the dead leaves of trees in freshly burned forests. Burned areas likely to provide an abundance of sprout and shrubby growth valuable to deer and other forms of wildlife can be easily mapped from aerial photographs.

Trees which have been damaged by insects or disease so that the leaves have become brown appear as black on infra red photographs, white on panchromatic photographs and in natural color on color photographs (Spurr and Brown, *op. cit.*). Such photographs are of considerable value in surveying damage caused by insects and disease.

As stated earlier, flooded areas can be mapped with considerable accuracy by using aerial photographs. Such photographs may be used to indicate flood damage caused by wildlife as well as damage to wildlife caused by floods. In the level, swampy, forested land of north central Minnesota, Hoene (1946) reported that drainage ditches were plugged by beavers and that the consequent damage to forests by flooding was appalling. According to Hoene, a Minnesota processor of table-size Christmas trees had recently taken aerial photographs and colored motion pictures of the flooded areas in order to show authorities how serious the matter had become. The aerial photograph used to illustrate Hoene's article showed very clearly the flooded, as contrasted with the non-flooded areas of coniferous forests.

As an Aid in Determining Hunting Pressure

On certain areas aerial photos could be used to good advantage in determining the number of hunters in the field at a given time. Large scale, continuous strip photos would be excellent for this purpose. Willet Wandell (*op. cit.*) indicated that two aerial flights had been made over northeastern Illinois for the purpose of determining hunting pressure and that air counts had been made to check the results obtained by ground counts. He indicated further that, although aerial photography equipment was lacking at the time of the survey, aerial photographs would have been very helpful in checking the accuracy of the aerial counts.

Other Suggested Uses

Among the other ways in which aerial photographs might be used in the wildlife conservation field are: (1) in locating,

mapping and planning potential dam sites; (2) in preparing soil erosion maps and spotting land-use and wildlife problem areas; (3) in determining changes in vegetative cover and land-use over a period of years; (4) in planning the locations of roads, trails, fire lanes, fire towers and other developmental features of newly acquired areas; (5) in making special studies of rare or vanishing species such as the whooping crane in which complete and permanent records of the habitat types utilized are desirable; (6) in conducting lake surveys including the mapping of emergent and floating aquatic flora and possibly the contour mapping of lake bottoms; (7) in accurately plotting tax delinquent lands in connection with the acquisition of land for game refuge and management areas and (8) in recording pictorially the features of breeding grounds, newly discovered in remote areas, resulting from the increased use of the airplane as a means of travel by biologists.

EXPLANATION OF ILLUSTRATIONS

The illustrations included with this paper demonstrate various types of aerial photography and indicate some of the uses that can be made of aerial photographs in the conservation field. 5D to 7C are verticals arranged in such a manner that they can be viewed through a stereoscope. Readers who have never used a stereoscope are urged to try one on these photos and note the added details which can be learned from a stereoscopic examination. It should be pointed out that original prints of good quality, properly arranged to meet the varying requirements of individuals will give more satisfactory results than these reproductions.

SUMMARY

The primary objectives of this article are to acquaint wildlife technicians with aerial photography and to suggest ways of obtaining aerial photographs and of utilizing them more widely and efficiently in the field of wildlife management. The literature dealing with the use of aircraft and aerial photography in the wildlife field is reviewed; types of aerial photographs are described; the status of aerial photography in the United States is indicated; criteria for selecting photographs for use in wildlife conservation work are discussed; means and methods of obtaining and interpreting aerial photographs are considered. Various types of aerial photographs including stereo pairs are included as illustrative material for study purposes.

Several uses for aerial photographs in the wildlife management field are suggested with the hope that they may be tested and that they may result in the further application of aerial photography in wildlife research and management. These suggestions include the use of aerial photographs as maps; as aids in evaluating and determining the extent of game range; in censusing such animals as big game species, muskrats, seals and waterfowl; in locating refuge sites; in law enforcement; in determining hunting pressure; in studying areas damaged by fire, floods, insects or disease; in locating, mapping and planning potential dam sites; in preparing soil erosion maps and spotting land-use and wildlife problem areas; in determining changes in vegetative cover and land-use over a period of years; in planning the locations of roads, trails, fire lanes, fire towers and other developmental features of newly acquired areas; in

making special studies of rare or vanishing species; in conducting lake surveys; in plotting tax delinquent lands in connection with land acquisition; and in recording pictorially the features of important but remote and relatively inaccessible breeding grounds of wild animals.

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BRIEFER ARTICLES

EFFECT OF BAIT IN LIVE TRAPPING *PEROMYSCUS*

The effect of the presence of baited traps on the normal travels of *Peromyscus* and the value of bait in inducing the mice to enter traps, were studied by trapping tests in the late summer of 1946.[1] The studies were made in the bottomlands forest of the Patuxent Research Refuge, Maryland. The wood mouse population, determined by live-trap quadrat studies, was about 6 adults per acre at this time.

Effect of Bait on Travels Relative to the Home Range

If small mammals travel outside their home ranges because they are attracted by bait, more of them will be caught in a trapped area than normally live there. This will make calculated populations too large by an unknown amount, and will likewise distort data on home ranges and exploratory travel.

Data concerning the effect of the presence of baited traps on the normal travels of wood mice was gathered in connection with other studies of these mice. In the first of these a plot of 8.4 acres in the form of an oblong with rounded ends had been live-trapped for six nights, with traps on a 50-foot grid pattern. Bait used was rolled oats and peanut butter. Mice had been marked and released at the places of capture. Plotting of the capture sites had shown the locations of the home ranges of the resident mice, although the complete home ranges had not been determined because of the relatively short trapping period. To find the possible effect of baited traps on the travels of these mice, a second trapping period was conducted in this same plot. Trap sets were placed at 300 foot intervals over the area, so that traps would not be present in the ranges of all the mice. Each set consisted of three traps placed within three feet of each other. This number of traps per station was adequate to capture all the mice that might have been trapped at this point, for only rarely were all three traps sprung. The traps were moved each night to positions at least 150 feet from any previously trapped site. The sets on any one night were always 300 feet apart. This second trapping period consisted of four nights trapping on this plan.

In this time 18 mice that had been marked in the first trapping period were recaptured. Their capture sites were either identical with or very near the sites where they were collected in the first period. There was no reason to believe that any of them had altered their normal travels to enter the baited traps. Eleven of the group were adult females. Seven of these were taken at the same locations both trapping periods; three were taken 50 feet and one 73 feet from their places of capture the first period. The locations of capture appeared to round out rather than extend the ranges of these four. The distances are probably not significant as they are equal to only the distance between traps in the first trapping period, and during this period the complete extent of range was admittedly not determined. Six of the seven adult males were trapped at the same locations each period and one was taken 50 feet from its site of capture the first period. Since the 50 foot grid trapping was carried on for several days in advance of the trial, it is likewise evident that pre-baiting to the extent it would occur in normal trapping did not cause an alteration of mouse range.

The conclusions from these two trapping periods were supported by evidence from an additional trapping study. In tests of line trapping (Stickel, Lucille F., 1948, The Trap Line as a Measure of Small Mammal Populations. Journ. Wildl. Man., **12**: 153–161) a 600-foot line of 40 live traps was operated through the center of an 8.4 acre plot both before and after the plot was trapped on a 50-foot grid. The mice trapped on the line were taken in or very near the ranges where they were caught in the area trapping. This study likewise gave additional evidence against a pre-baiting effect as a result of trapping operations, for the catch of the line of traps prior to the grid trapping was the same as it was afterwards.

[1] Acknowledgments are made to David Kemp, Harold Angle, and Charles Schaffer, who assisted with various parts of the field work.

EFFECT OF BAIT ON NUMBER OF MICE ENTERING TRAPS

It is well known that *Peromyscus* will frequently enter unbaited traps, and there have been indications that the inquisitiveness of the mice and the thoroughness with which they explore their home ranges make the use of bait unnecessary. A trapping test was planned to determine whether the use of bait would significantly increase the catch by improving the efficiency of the traps. In these trials two lines of traps were placed about 350 feet apart. Each line consisted of 40 traps spaced at 15 foot intervals. Large sized Sherman live traps were used. These traps were new and had not previously contained bait. Cotton nesting material was placed in the back of each trap

Both rows of traps were operated without bait from August 16 through 20. On August 20 the traps in Row A were baited with rolled oats and peanut butter. The traps in Row B remained unbaited. Both lines were operated in this manner from the 21st through the 25th of August. Each line caught seven mice while both lines were unbaited. In the second period, captures by the unbaited line increased from seven to 11, an improvement of 57 per cent. At the same time the baited line caught 25 mice, an improvement of 257 per cent over its catch when unbaited. Weather was more favorable for trapping in the second period, which probably accounts for part of the increase, as indicated by the larger catch of the unbaited line. Detailed results are shown in Table 1.

TABLE 1.—NUMBER OF INDIVIDUALS CAUGHT IN BAITED AND UNBAITED TRAPS

	Row A		Row B	
	Period I Unbaited	Period II Baited	Period I Unbaited	Period II Unbaited
Males	5	17	6	9
Females	2	8	1	2
Total mice	7	25	7	11

It is apparent that the catch of wood mice was increased significantly by the use of bait in the traps. The reason for the increase was apparently the added inducement of bait within the traps, for evidence is given in the first part of this paper to show that these animals do not ordinarily wander from their normal ranges to enter baited traps.

SUMMARY

Evidence from live trapping tests indicated that *Peromyscus leucopus* did not leave their home ranges because of the attraction of trap bait in nearby areas.

A trap line down the center of a heavily live-trapped area caught as many mice before the area trapping as afterward. Thus, there was reason to believe that the area trapping did not serve to pre-bait the mice.

Two unbaited lines of live traps caught an equal number of *Peromyscus*. When one line was baited with rolled oats and peanut butter the efficiency of the traps was improved to the extent that the baited line captured more than twice as many mice as the unbaited line.

It is concluded that for the species and habitat tested it is safe to make population calculations based on the assumption that the animals remain within their home ranges and do not tend to move into the trapped area because of the attraction of the trap bait.—LUCILLE F. STICKEL, *U. S. Fish and Wildlife Service, Laurel, Maryland.*

IMPROVED TOE-TAG FOR MARKING FOX SQUIRRELS

In life history and management studies of the fox squirrel, considerable difficulty has been encountered in maintaining identity of individual animals during subsequent handlings. Many valuable records have been lost by sloughing or tearing out of identification tags.

As an aid in maintaining identity, a double tag system has been used to identify squirrels taken during live-trapping operations at the Rose Lake Wildlife Experiment Station in Michigan. As each animal is first handled, an ear-tag and toe-tag are attached for future identification. The eartag is a number 3 small mammal tag (Style no. 1005 of the National Band and Tag Company, Newport, Kentucky), and is applied by applicator to the right ear in males and left ear in females. As a double check on the animal, a toe-tag is added to the hind foot. This method of toe-marking fox squirrels has been described previously (Linduska, 1942). This involved the use of numbered fingerling tags, applied to the basal joint of the outer toe of the hind foot.

After considerable experience with this method of marking, it became evident that a modification of the system was necessary. Squirrels were continually appearing in traps with a torn ear and the outer toe of the hind foot either swollen and festered or missing. A slight degree of infection and irritation invariably follows the application of the ear-tag, and in severe cases the tag is sloughed out. The percentage of loss is sufficiently high to make the use of ear-tags alone unreliable. For this reason toe-tags have also been applied. The difficulty in using fingerling tags came principally through the method of application. The tag was applied by a pliers-type applicator, flattening the tag in the process. It was then adjusted by rounding to a comfortable fit. Slight injury to the toe was usually unavoidable, as when the tag sealed, the toe was pinched and occasional swelling followed. Even though the rounded tag was loose enough to turn freely at the time of application, a restriction of circulation generally followed with subsequent loss of the toe and tag. Also, the use of this type of tag was clumsy and time-consuming to apply, especially in mosquito-infested woodlots.

It was believed that a circular toe band of the proper diameter applied like a bird band would prove more satisfactory. From the ensuing work, the improved toe-tag described was developed.

A special circular band of monel metal, manufactured by the National Band and Tag Company, was constructed to our specifications. A diameter of $\frac{3}{16}$ inch and width of $\frac{1}{8}$ inch were measurements used, taken from an average of several toe measurements. These bands, consecutively numbered and rounded by the manufacturer, are applied by an ordinary pair of needle-nose pliers. The outer toe of the hind foot was used at first for attaching this tag, but it was found in several cases, particularly with young squirrels, that the tag would slip over the basal joint and cause stoppage of circulation, with resultant sloughing of the toe and tag. The inner toe was then used, having one less joint to contend with. On this toe the tag worked very well and no case of infection or loss of toe has been noted. The tag fits loosely yet is held on by the large toe-pad.

During the 1946 hunting season, several squirrels were checked which had only the improved toe-tag remaining for identification, providing valuable information on the life history of these animals.—MARVIN E. COOLEY, *Game Division, Department of Conservation, Lansing, Michigan.*

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BEAVER CENSUSING BY AIRPLANE

An inexpensive, quick, and reliable, census method was needed in the formulation of a plan for beaver (*Castor canadensis canadensis*) management being conducted under the Federal Aid in Wildlife Restoration Act in West Virginia. As an experiment an Ercoupe airplane was used in two census flights over mountainous, isolated areas known to contain large numbers of beaver colonies. These flights were made on April 19 and 29, 1947, before the leaves came out on the deciduous trees. Few data were taken on the first flight as it was made merely to determine to what extent beaver colonies were visible from the air. Sunlight reflected from beaver ponds made them visible for a considerable distance. Lodges surrounded by water were very easily seen, but bank lodges were visible only upon close observation. U. S. Geological Survey Quadrangle sheets proved satisfactory for marking the location of colonies. A map without contour lines proved unsatisfactory due to difficulty in determining the exact location of colonies.

On the second flight 103 miles of stream, believed to contain 54 beaver colonies, were covered in 45 minutes. Areas surveyed were portions of Blackwater River, Beaver Creek, Stony River and Red Creek. Flying time from Elkins airport to the area and return was 45 minutes. Cost of the one and one-half hour flight was $21.50; $18.00 for rental of plane and $3.50 for pilot fee. It would have been practically impossible to census this same area by ground survey methods due to the inaccessibility of the area and the time required. The costs certainly would have been prohibitive.

To use the data for census purposes it was necessary to determine the average number of beaver per colony. Limited live trapping of beaver in West Virginia during September and October of 1946 indicated that there was an average of 5.3 animals per colony. This agreed closely with 5.1 animals per colony in Michigan as determined by Brandt (Journ. Mammalogy, 19(2): 139) during the summer of 1931. Thus the 103 miles of stream contained approximately 286 beaver according to this method of censusing.

It is our opinion that a satisfactory beaver census can be accomplished by using an airplane. Two sources of errors encountered are: (1) difficulty in determining the number of colonies on a stream which has a series of many beaver dams close together; and (2) failure to determine the number of bank beaver. The same two errors are encountered in censusing by foot, but probably to a lesser extent.

A more satisfactory beaver census would result if taken in the fall after the leaves have fallen. Beaver activity is greatest at this season and for management purposes a census is needed just prior to the trapping season. From an air census standpoint best results are obtained during fair, calm weather. Such optimum conditions are usually found early in the morning. Any weather condition which would be classed under C.A.A. Contact Flight Rules would be satisfactory. A low wing plane with only 75 horsepower like the Ercoupe has many disadvantages for aerial reconnaissance work of this type. A high wing monoplane with at least 125 horsepower and flaps would be desirable in areas where the terrain is mountainous and rugged. More vision and a better margin of safety would be provided. Censusing of beaver in severely dissected terrain in an underpowered plane can be dangerous. A stable plane with low cruising speed would help when tallying observations and favor the comfort of the non-airminded passengers.—WENDELL G. SWANK and FRED A. GLOVER, *Conservation Commission of West Virginia, Elkins, W. Va.*

REVIEWS

Fishery Resources of the United States. Edited by Lionel A. Walford. Public Affairs Press, Washington, D. C. iv+134 pp., illus. 1947. $5.00.

Released originally as a government bulletin (Senate Document 51, U. S. Government Printing Office, Washington, D. C., 1945), this document has been reprinted in book form. Although its contents remain the same, its appearance is somewhat different in that the illustrations are reproduced in green ink, and a cloth cover, end papers, and a jacket have been added.

Presenting a great amount of general information in a concise yet readable manner, the book is especially outstanding for its very attractive format. According to the preface, the text is "from material collected by the staff of the Fish and Wildlife Service." Though the quarto size is somewhat unhandy, the large pages permit the presentation of abundant sketches of fishes and other aquatic organisms, maps showing their geographic and ecological distribution, diagrams of fishing methods, graphs, charts and photographs.

The volume is divided by the principal headings: Pacific Fisheries Resources, World Fisheries Resources, Atlantic Fisheries Resources, Fresh Water Fisheries and Great Lakes Fishery Resources. Under each topic, the various aquatic species concerned are discussed from the standpoint of sustained-yield production. Life history data, management methods, cropping techniques, catch and cash value totals for previous years and potential development of the resource are discussed where they relate to production. The complete range of economically important aquatic organisms is covered, including the valuable sponges, molluscs, crustaceans and turtles. Fur seals and whales are given treatment comparable to that applied to the cold-blooded vertebrates. Even seaweed utilization and frog culture are mentioned, and brief accounts of pond fish culture, Hawaii and Puerto Rico fisheries resources, the economics of U. S. fisheries, and the relation of dams and land mis-use to fisheries resources are diagrammatically illustrated.

The fresh-water fisheries are not treated nearly so thoroughly as the oceanic aquatic resources. Only 14 pages are devoted to inland fisheries, 4 of which are on the Great Lakes fisheries. The discussion of fresh-water game fishes is extremely limited (oysters are allowed 6 pages, trout 2). The data on economics of U. S. fisheries apparently is confined to commercial fisheries, overlooking entirely the large sport fishing investments. The index is confined to an alphabetical listing of species.

Though the expansion of some sections would have been desirable, the book fills a decided need and doubtless will be employed widely as a general reference on aquatic life and its values. The volume deserves considerable recognition as one of the few really attractive scientific publications prepared originally by the government. It could very well be complemented by a similarly compiled companion volume on the other wildlife resources of the United States.—GEORGE A. PETRIDES.

Fish Ponds for the Farm. By Frank C. Edminster. Charles Scribner's Sons, New York City. xii+114 pp., 12 figs., illus. 1947.

In his book on farm ponds, Mr. Edminster has made a notable contribution to wildlife literature designed for layman consumption. Written in simple and beautiful non-technical language, it gives an interesting and enlightening background of pond fish culture, and leads the reader through a maze of technical problems involved in farm pond construction in such a skillful manner that one emerges with the "know how" even if the transit and the clam-dozer are still operational mysteries. The chapters "Location of the Pond" and "Building the Pond," are based on the results of engineering research covering many years of actual farm pond construction by engineers of the U. S. Soil Conservation Service. Few are those who can relate an instance of dam failure on a pond engineered by that Service!

A chapter, "Landscaping the Pond Area" will motivate many a landowner whose thoughts have been more or less casual on farm ponds. Planting suggestions and illus-

trations conjure a mental picture of the "loveliest spot on the farm—a place where all the family want to spend their spare time," a natural setting for picnics and wiener roasts, with swimming and fishing in summer; and skating in winter.

The latter part of the book deals with the management of the farm pond for the production of fish for sport and table. There is a section on the renovation of old ponds that have been improperly stocked, have been contaminated with undesirable fish or have become unproductive through neglect. These ponds when drained or poisoned and restocked may be made to produce a fish crop. Extensive experience with rotenone as a fish poison has shown however, that a dosage figured on "cubic feet of water divided by 24,000 gives the number of pounds of rotenone needed" (p. 73) will not always be sufficient to give a complete kill. A safer dosage calculation would result from the use of 15,000 in place of 24,000.

Every fisherman should read the chapter "Some Fundamental Biological Facts and Principles" because the author's statements apply not only to ponds, but to all fishing waters. Until sportsmen and legislators understand and accept these biological principles relative to reproduction and growth of fishes, to the carrying capacity of waters for fish, and to the role of fish predators, state laws governing the taking of fish will continue to block sound fish management.

In the chapter titled "Developing Good Fishing" the author recommends the use of a combination of largemouth bass and bluegills as being preferable to all others. This is probably as it should be, yet fisheries biologists who have had extensive experience with this combination and others can site instances where the bass-bluegill combination has produced little fishing or eventually has given a poor yield, after an early period of good fishing. On the other hand, other combinations of fishes have been known to produce a fish crop equal to that of the most productive bass-bluegill lake. Lack of a uniformity of success with the bass-bluegill combination in the midwest may relate in part to the fact that bass have never been known to spawn at one year old even when they had reached weights of eight to nine ounces. This is substantiated by histological studies of the gonads of largemouth bass (James, Marion F., 1946. Histology of gonadal changes in the bluegill, *Lepomis macrochirus Raf.*, and the largemouth bass, *Huro salmoides* (Lac.), Journ. Morph., **79**(1): 63–92) of known age from central and southern Illinois. Where bass mature at two years and bluegills at one, the stocking of bluegill and bass fry at the same time may allow an excessive build-up of bluegills before the bass become sexually mature, and stocking ratios of 1 bass to 10 bluegills quickly result in an overpopulation of bluegills.

The discussion of pond fertilization is unfortunate because it implies that fertilization is necessary for good fishing and forces a pond owner to spend a minimum of $20 per acre of pond per year to maintain "elbow depth turbidity." It has been amply shown that good fishing is a function of population control, and in many cases where fishing pressure is moderate it is much easier to maintain correct ratios of predator and prey fish and good fishing in an unfertilized than in a fertilized pond. Up to the present, however, pond fertilization is the surest and safest method of controlling rooted underwater vegetation.

The term "balance" as applied to ratios of numbers of bass and bluegills in a pond is to imply a static relationship which does not exist. Just what "balance" is in terms of relative numbers of bass and bluegills is not explained, but recommended stocking ratios imply that it is about 1 to 10. Experience with the minnow seine method of sampling ponds to test their "balance," in a number of cases where the larger fishes were being intensively studied by other methods, indicates that little information on the adult bass-bluegill population or the kind of fishing that the pond will produce may be gained by seining up their young along the pond edges.

In the last chapter, "The Fish Harvest and Pond Maintenance" the author recommends heavy fishing and the taking of all fish regardless of size as a means of perpetuating good fishing. Granting that heavy fishing is necessary for the production of a sustained yield, in actual practice it is nearly impossible for the farmer-owner to recruit enough fishing pressure. Most private farm ponds are so

badly under-fished that they rapidly become non-productive because of overpopulation and stunting of the fish. Ponds that produce sustained yields over a long period of years are usually those owned by fishing clubs with a large membership of enthusiastic fishermen. No mention is made of the fishing pressure required to take an annual crop of 150 to 200 pounds of fish per acre, nor are other methods of cropping suggested where angling pressure is light.

This book contains much factual information on ponds. Its shortcomings are in an over-simplification of pond management and over-optimistic statements of average fish yields.—GEORGE W. BENNETT.

The Mammals of Virginia: *An account of the furred animals of land and sea known to exist in this commonwealth with a list of fossil mammals from Virginia.* John Wendell Bailey, Richmond, Virginia, John Wendell Bailey (privately published), xvi+413 pp., 96 figs. December, 1946. $5.00 (a 20 per cent discount is allowed wildlife workers).

Dr. Bailey has brought together and published the first lengthy report on the mammals of Virginia. Contained in this work is an extensive account of the history of mammalogy in Virginia, dating from a report of Harriot in 1588, and a list of the fossil mammals known to have existed in the state. This list of 41 includes 7 mammals which occurred or occur in Virginia within Recent time. Unfortunately, no mention is made where these fossils have been found in the state. One hundred thirty Recent mammals are listed as occurring in the state.

Preceding the accounts of kinds of Virginian mammals, there are chapters on habits and habitats, economic importance, conservation, classification, and features useful in identifying mammals. Bailey would have done better, in our estimation, to have more completely restricted his comments in these chapters to pertinent facts concerning Virginian mammals. The chapter on "The Conservation of Wild Life" is of interest for Bailey reviews briefly the bounty laws of the state, the classes of wildlife takers, suggests a "fair" way of assessing the hunter for the privilege of taking game, and lists and maps the wildlife refuges in the state. Bailey's idea of game management (p. 49) through "elimination" of natural checks (enemies) is unsound. The student of wildlife will dislike the inclusion, with lengthy accounts, of fourteen kinds of domesticated, non-native mammals, including the guinea pig and mule. Most mammalogists would not consider the mule a distinct kind. Many mammals, both terrestrial and aquatic, are included although they have never been taken in the state. For example, at least 10 cetaceans are included for they most undoubtedly occur in waters "off" Virginia, even though it may be several hundred miles in several directions from Virginia whence they have actually been taken. In Bailey's estimation, for each "its cosmopolitan distribution warrants its inclusion here." If these mammals had to be included, a more proper place for them would have been in a list of "kinds probably occurring in Virginia."

The accounts of the Recent mammals occupy about two-thirds of the book. Included therein is a brief statement about the order, family, genus, and species, as well as the subspecies. The accounts of the species are of more value, in our estimation, than those of the subspecies for the author did not examine sufficient specimens to accurately characterize the subspecies or define the limits of their range when two or more subspecies of one species occurs within the state. The real value of such accounts, in any book, lies in defining the limits, both morphologically and geographically, of the subspecies. Perhaps if more specimens had been available to the author, distribution maps would have been included. Information in the various accounts represents a compilation of material already published, and little new information about Virginian mammals is presented. Some of that which is given seems ambiguous or poorly stated, such as "The young [*Sorex longirostris fisheri*] probably remain in the nest until grown . . . ", "The first thing the parent wolves teach their young is to fear all mankind," or the statements that muskrats *are* mainly nocturnal but *often* are seen during the day, and jumping mice need to creep up on their prey. These are only a few of a long list of such

statements, and together with typographical errors, as for example, *Euaretor* for *Euarctos*, detract from the value of the book.

Dr. Bailey's book would have profited by additional field work and collecting. These short-comings however cannot help but stimulate aspiring mammalogists and wildlife workers to further investigations in the state of Virginia.—LOWELL S. MILLER AND DONALD F. HOFFMEISTER.

NOTE

Data from many sources indicate that trends of change in the dynamics of the populations of many animals tend to be cyclic. In addition there is a tendency for the stage in the population cycle for a species to be in phase over wide geographic areas. The Rodent Ecology Project of the Johns Hopkins University is sponsoring the initiation of a cooperative program using a standardized sampling technique to investigate this problem further. Emphasis is placed on the sampling of small mammals such as *Microtus*, *Sigmodon*, and *Peromyscus*. Prospective cooperators and others interested in this program may receive a detailed description of it by writing John B. Calhoun, Rodent Ecology Project, Johns Hopkins University, 615 North Wolfe Street, Baltimore 5, Maryland.

OBITUARIES

ROBERT WARD ALLEN
1913–1943

Robert W. Allen, biologist of the Fish and Wildlife Service, was one of the members of The Wildlife Society who lost their lives in the recent war.

He was born at Ossian, Iowa, October 16, 1913. His parents, Ward Malcolm Allen and F. Fern Cornell Allen, and a brother survive him. Mr. Allen graduated from the Ossian public schools and Iowa State College, receiving his B.S. degree in zoology in 1935. The following year he took the M.S. in zoology at the University of Michigan and began work toward a Ph.D. in ornithology under Dr. J. Van Tyne.

The spring and summer of 1937 he was employed by the U. S. Forest Service in deer research on the Pisgah National Forest. When this project was terminated he returned to his doctoral work at Ann Arbor. In March, 1939 he became a biologist in the Soil Conservation Service, a position he held until April, 1940. He was stationed briefly at Howell, Michigan, but the greater part of this time was spent at Santa Fe, New Mexico. Several months of doctoral study followed. Mr. Allen joined the Fish and Wildlife Service as a biologist at the Blackwater National Wildlife Refuge, Cambridge, Maryland, in October, 1940. Here he assisted Dr. Herbert L. Dozier in studies of muskrats and other fur animals, and with him was author of a paper on the color, sex ratios, and weights of Maryland muskrats (1942. Journ. Wildl. Mgt., **6**(4): 294–300).

He was inducted into the army in January, 1942. Because of his patriotism and intense hatred of the tyranny represented by the enemy he chose to become a turret gunner in the tank corps. His slight physique proved unfitted to this work. Serious injuries suffered during training led to prolonged hospitalization. After recovering he transferred to the malaria survey work then being organized by the army, and went to Australia and New Guinea with the 4th Malaria Survey Unit. He drowned in a New Guinea river in October, 1943.

In personality he was quiet, but friendly, and almost invariably cheerful. He loved fishing, hunting, and travel, but his strongest interest was ornithology. The phase of ornithology that he enjoyed most was the study

of bird behavior. He felt that detailed field studies of the behavior of single species afforded one of the most valuable and fascinating aspects of ornithology. His doctoral research was a study of the breeding biology of the purple martin. Most of the field work was done at the George Reserve of the University of Michigan, largely in 1938 and in 1940. At the time Mr. Allen entered the army the preparation of his thesis was well advanced. It is hoped that all or part of it can be published as a lasting memorial to this able young biologist.—WILLIAM H. STICKEL and ROBERT E. STEWART.

EDWIN GEORGE BAETJER
1868–1945

Edwin George Baetjer, a member of The Wildlife Society from 1938, died in Baltimore, Maryland, July 20, 1945. He was born in that city June 25, 1868. After preliminary education, he was graduated from the University of Maryland Law School and was admitted to the bar in 1890. He was very successful in this profession in which he continued until his death—a period of 55 years.

He was actively interested in city and State welfare but refused political preferment. In the period of World War I, he was Chairman of the Draft Appeals Board of Maryland and also Food Administrator for that State. For exceptional services in these capacities, he was awarded a Liberty Service Medal by the National Institute of Social Sciences. With a small group of social-minded Baltimoreans, Mr. Baetjer was instrumental in founding the Community Fund. He was Chairman of the Committee that inaugurated the city's Civil Service Commission and acted as Chairman of the Merit System for a term. He was a member of the Board of Trustees of Johns Hopkins University from 1928. He was also a Trustee of McDonogh School and of the Peabody Institute. Although unmarried he had both city and country homes. His clubs were Maryland and University of Baltimore and Links of New York.

A world traveler, he hunted and fished whenever opportunity offered. He had a shooting box in Scotland and a fishing lodge in Canada. There he was a member of the Ristigouche Salmon Club and helped to formulate policies for the restoration and management of their favorite fish. He was advisor to Maryland Governors on the conservation problems of the State, also a member of the Maryland Board of Natural Resources from 1941 to his death. Mr. Baetjer collected and organized a vast amount of information on oysters and the oyster industry of Maryland and at personal expense reprinted for wider distribution the Fourth Report of the Maryland Board of Shellfish Commissioners, on the most complete oyster survey that has ever been made.

He was the leading member of a shooting club in South Carolina and supported a game-bird farm near Petersburg, Virginia. Here the manager, W. B. Coleman, was enabled to continue development of methods of quail propagation, in which he had been engaged since 1913, including electrical incubation and brooding. The bobwhites produced on the White Oak Quail Farm were sold for restocking in Virginia and other states and some were sent to the Pineland Club in South Carolina. More than 13,000 birds were reared in some years. Less extensive propagation was carried on of other species, including the ruffed grouse, prairie chicken, and chukar and red-legged partridges.

Herbert L. Stoddard courteously informs me that Mr. Baetjer was a Non-Resident Member of the Cooperative Quail Study Association from 1934 until the Pineland Club was sold. There for several years he conducted extensive experimental and developmental work for the improvement of quail habitat in cooperation with the Association. He was considered one of the most valuable and energetic supporters of the organization and he had great confidence in the scientific approach to wildlife management, and was always eager to try out, at his own expense, recommended procedures for game-habitat improvement.

Mr. Coleman, who has kindly provided certain details for this statement, writes: "Mr. Baetjer was truly a gentleman of the old school—one of the grandest men it has ever been my good fortune to know. He was

a great hunter and fisherman, a sportsman from the ground up, always keenly interested in the conservation and propagation of our wildlife and contributed very generously to the cause. Mr. Baetjer was, of course, a very able and successful attorney. His passing on is a great loss to the country."—W. L. McATEE.

MAURICE LAYTON HINSHAW
1911–1947

Maurice Layton Hinshaw, a member of The Wildlife Society from 1945, was born December 26, 1911, in Rochester, Indiana. The family evidently led a roving life for he attended 16 different grade schools, ending at Whitman School in Wenatchee, Washington, where he completed the course in 1927. He then spent four years in the Wenatchee High School, graduating in 1931. Further education included two years at the University of Washington, Seattle; a pre-medical course in 1931; and one in forestry in 1935. He received the B.S. degree in biology from Rollins College, Winter Park, Florida, June 1941. He was married at Forsyth, Georgia, on June 14, 1941, to Elizabeth Leigh Davis.

Positions held were museum assistant at Rollins College, 1937–38; field assistant, Oregon Cooperative Wildlife Research Unit, 1941–42; laborer-patrolman, Tule Lake Wildlife Refuge, 1942–43, and junior soil scientist, Soil Conservation Service, 1943–44. On April 1, 1944, Mr. Hinshaw was transferred to the Fish and Wildlife Service as refuge manager of the Tule Lake Refuge, Tule Lake, California, and later to the Willapa Refuge in Washington.

His hobbies were amateur photography, hunting, and fishing.

While on duty, May 23, 1947, Mr. Hinshaw anchored his boat on the flats and went about the performance of his official duties. When he came back to the boat the tide was in and it was necessary for him to go into the water to reach the boat. He pulled off his clothes and left them on the bank, also left his dog there, and was last seen (from an airplane) walking from the bank toward the boat. He has never been seen nor heard from since, so it is presumed that he drowned. Mr. Hinshaw left a widow and a 4-year old daughter named Virginia Lee Davis Hinshaw.—EDNA N. SATER.